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Ecosystem Services and Peter Calthorpe's Model of Transit-Oriented Development: Prospects and Challenges for City Planning

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Ecosystem Services and Peter Calthorpe's Model of Transit-Oriented Development: Prospects and Challenges for City Planning

by

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Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Community and Regional Planning

The University of Texas at Austin

May 2012

Abstract

Ecosystem Services and Peter Calthorpe's Model of Transit-Oriented Development: Prospects and Challenges for City Planning

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The University of Texas at Austin, 2012

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This study explores the non-monetary values assigned by designers, planners, developers, and policy makers in integrating ecosystem services into the design and development of urban transit-oriented development (TOD). This thesis also investigates the theoretical and practical design strategies that incorporate ecosystem services into Urban TODs. Methods used for research and data collection included reviewing existing literature relevant to the subject matter, conducting interviews with policy makers, academics, and design professionals, and exploring two specific examples of progressive, urban, "green," TODs in the Pacific Northwest. This study concludes with ideas for future research into the integration of ecosystem services into urban TOD planning, and potential urban environmental policies that can be adopted by municipalities to maintain and strengthen the ecosystem services of the growing metropolis.

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Chapter 1: Introduction and Literature Review

> "Above all we should, in the century since Darwin, have come to know that man, while captain of the adventuring ship, is hardly the sole object of its quest, and that his prior assumptions to this effect arose from the simple necessity of whistling in the dark.
>
> These things, I say, should have come to us. I fear they have not come to many.
>
> For one species to mourn the death of another is a new thing under the sun. The Cro-Magnon who slew the last mammoth thought only of steaks. The sportsman who shot the last [Passenger] pigeon thought only of his prowess. The sailor who clubbed the last auck thought of nothing at all. But we, who have lost our pigeons, mourn the loss."
>
> -Aldo Leopold, *A Sand County Almanac*, 1948, pgs. 109-110

The objective of this study is to examine the non-monetary values assigned by designers, planners, developers, and policy makers in integrating ecosystem services into architect, urban designer, and planner Peter Calthorpe's model of urban transit-oriented development, most commonly used in North America. Ecosystem services are defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997, 253). Examples of ecosystem services include clean air, clean water, climate regulation, food production, pollination services, and soil fertility. This study will further assess how the values identified by design professionals and academics, developers, and policy makers can translate into urban environmental policy that effectively strengthens and maintains the ecosystem services of a growing metropolis.

In order to fulfill this objective, the following three questions will be addressed throughout this report:

1. How have ecosystem services been incorporated been incorporated into

the design and development of Urban TODs?

2. What are the *values* of incorporating ecosystem services into the design and development of TOD as articulated by designers, planners, developers, and policy makers?
3. What is the historical development of policies that support the integration of ecosystem services into the design and development of TODs and where is policy currently needed to further facilitate this integration?

Aldo Leopold recognized that while we have evolved to understand that human beings are only a part of the intricate web of life, dependent on the health of the global ecosystem to sustain our own existence, we have failed to take systematic action based on this knowledge. Though we mourn the loss of the [passenger] pigeon, we continue to develop in environmentally unsustainable ways, harming the habitat of other animals and human beings as well. As the renowned environmental planner Ian McHarg said, "[l]et us ask the land where are the best sites" (McHarg 1969, 197). Since McHarg's time, the planning profession has expanded to incorporate environmental analysis into the design and development of the built environment. However, there still exists a lack of cohesion and a failure to include site, city, and regionally distinct ecosystem services into planning practice. In order to move towards sustainable urban environmental development that enhances the quality and quantity of urban ecosystem services, creative policy that supports this integration is vital.

THE CONTEXT OF URBAN ECOSYSTEM SERVICES

In the mid 1990s, a new environmental movement emerged. This movement was different than the highly political environmental movement that occurred in the United States during the late 1960s and early 1970s, spurred by the visible degradation of primarily air, water, and communities of species, and spearheaded by non-governmental agencies (NGOs). The key difference between these two environmentally progressive eras was that this movement, on the cusp of the new millennium, was rooted in quantitative economic analysis. The key leaders—economists, ecologists, and biologists—went a step further than their predecessors. They built upon the idea of the dependence of the human race on nature, and placed this reliance it in the context of a globally interdependent, 21st century civilization.

A few unprecedented, significant, and enduring events took place during 1990s which motivated these environmental leaders and scholars to translate the empirical data observed within their fields into the universal language of the times, economics. First, the 1990s was a decade of prolific technological innovation. Technological systems created at the beginning of this decade modernized communication, resource extraction, production of food and goods, delivery of services, and international travel and shipping. These innovations made it easier to conduct domestic and, primarily, international trade in a timely and less costly manner. International emphasis on economic development and the importance of a high Gross Domestic Product (GDP) amplified quantities of extraction, production, and trade of imports and exports, internationally. "Globalization," or the economic movement between nations, was increasingly significant. National economies which had previously been distinct entities became interdependent; one nation's success or failures intimately affected the economic prosperity of another nation.

Cheaper raw materials, production, and trade enabled the high consumption patterns already present among the developed nations. Essentially, it became inexpensive to consume at quantities which far exceeded one's basic needs. This consumption had to be supplied, and the effect of the production and international delivery of cheap goods and services on the natural environment was, and continues to be, catastrophic. Air, water, forests, soil, and biodiversity were among the natural resources with degraded quality due to this rapid consumption and economic growth (Wackernagel and Rees 1998).

Additionally, during the 1990s, amidst rapid technological innovation, the population of the world's cities reached three billion people, an increase of 50 percent in only 10 years (Wackernagel and Rees 1998). This growing urban population posed considerable questions about environmental quality, locally and abroad. As William Rees notes in his article "Life in the Lap of Luxury as Ecosystems Collapse," although cities are vital epicenters of cultural and economic growth, they are also places of vast material consumption and waste generation (Rees 1999). The potential forms of development to be encouraged for more environmentally sustainable communities fluctuated between higher density urban and lower-density suburban developments. Studies conducted during the mid-1990s revealed that cities could be more environmentally and economically sustainable than their lower density counterparts, despite their higher rates of consumption, waste production, and the fact that they required resources from far away to function. In *Cities and Sustainable Development,* for example, Diana Mitlin and David Satterthwaite emphasize that benefits to the natural environment occur when higher-density urban populations utilize city infrastructure, particularly infrastructure which aids in environmental sustainability (Mitlin and Satterthwaite 1994). Greater use of public transportation and municipal recycling programs, for example, result in an economy of scale, thereby producing the necessary returns which make these programs both environmentally and economically worthwhile (Rees 1999). This idea has been confirmed in recent years in New York City, America's most dense city, where the average dweller generates almost 70 percent less greenhouse gases than the typical American (Owen 2009).

During the 1990s, it was clear that the trend of human migration from rural to urban settlement was increasing. Prior to that time, and certainly during the latter part of the 20th century, the tendency in human settlement was toward rural and suburban areas. The idea that this trend toward urban life could be more environmentally sustainable than the suburban settlement patterns which dominated the second half of the 20th century spurred a new school of thought which explored city dwelling as a possible solution to the world's environmental ills.

The final and perhaps most significant event which influenced the movement of the 1990s was the world-wide increase in knowledge of and attention to human induced "global warming" (this terminology preceded "climate change," which has become the common lexicon and will be the term used in this study). Though scientists since as early as the mid- 19th century speculated that changes in atmospheric gasses could alter Earth's climate, it was the United Nations General Assembly formation of the World Commission on Environment and Development (WCED) in 1983 (which became known as the Brundtland Commission when Gro Harlem Brundtland, a Norwegian politician and leader of sustainability, was appointed Chairman in 1983), and the subsequent 1987 highly esteemed and widely circulated publication *Our Common Future* (also known as the "Brundtland Report") which brought the controversial idea of human induced climate change into the forefront of international political discussions during the 1990s (The American Institute of Physics 2011; Blowers and Glasbergen 1996). These discussions prompted greater exploration into the causes of global warming and led to cooperative agreements among over 100 countries to adopt more stringent environmental regulations to prevent temperature increases and to mitigate the potential impacts. Essentially, in the decade following *Our Common Future* it became public knowledge that climate change was a planetary issue which threatened the quality of life and the survival of all species.

Many people accepted that climate change was primarily the result of humans' exploitation of natural resources and depleted environmental resources (this latter idea still remains controversial among some groups today, though mostly in the U.S., as well as some leaders in China and India). The science became clearer to most people all over the world—it was accepted that the burning of fossil fuels, for example, releases large amounts of carbon dioxide (C02), a primary greenhouse gas. It was also accepted that the process of deforestation generates a large amount of CO2, in addition to depriving the natural environment of a valuable resource that sequesters large amounts CO2.

The way in which *Our Common Future* framed climate change, in addition to a number of the world's other ecological and social ills, as a "tragedy of the commons," was highly significant. That is, the report clearly illustrated that development of all kinds (economic, social, infrastructural) in one nation or area is not isolated but rather can have negative social or environmental consequences elsewhere on goods that belong to the global public, such as clean air, clean water, and a planet with a stable temperature. The first point listed under "Symptoms and Causes" in the report states:

> The Earth is one but the world is not. We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impact on others. Some consume the Earth's resources at a rate that would leave little for future generations. Others, many more in number, consume far too little and live with the prospect of hunger, squalor, disease, and early death (WCED 1987)

The idea that some countries impact global ecological systems and global warming more than others, and that these impacts could be felt in decreased environmental quality around the world, painted the picture of climate change as a universal problem which would require comprehensive international solutions. The future goal, the report stated, is sustainable development, which was defined as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" (WCED 1987). This definition of sustainable development has been the most widely adopted definition to date.

In response to these events—rapid globalization, increasing urban populations, global depleted and devastated natural resources, and the threat of global warming—a new environmental movement emerged. This movement sought to quantify humanity's ecological consumption and the true value of ecosystems, in order to emphasize the importance of preserving the world's ecosystems and the vital services which they provide. The quantitative analysis conducted during the late 1990s by economists and biologists provided a greater understanding of the following:

- The vast amount of non-renewable inputs required to maintain a human life with varying degrees of consumption.
- The amount of natural resources required to sustain an increasing population.
- The effect of past, current, and future consumption patterns on the natural environment.
- The relationship between the built environment—urban, suburban, and rural—and the consumption rates of these settlement patterns in developed and developing nations on natural resources
- The true monetary value of natural resources, and the externalities and opportunity costs associated with the high consumption rates of an increasing global urban population.
- The advantages of performing a life-cycle assessment on consumption goods and infrastructure for environmentally sustainable development solutions.

- The necessary trajectory for economic and infrastructural development in order to minimize human induced climate change, and to mitigate existing environmental harm.

The idea was that this information was to be used to encourage smarter future economic and infrastructure development that would preserve, restore, and enhance the vital services provided by the world's distinct ecosystems.

The quantitative-based environmental movement of the 1990s was initiated by the highly influential 1996 publication of *Our Ecological Footprint*. Stunned by the increasing global rates of per capita consumption, the resulting environmental degradation, and the failure of the prevailing economic system to account for and discourage the patterns of development causing this degradation, William Rees and Mathis Wackernagel developed a tool to illustrate humanity's unsustainable material dependence on natural resources (Wackernagel and Rees 1998). Rees, a population ecologist and professor of urban planning at the University of British Columbia, and Wackernagel, a planning Ph.D. student at the time and presently the President of the Global Footprint Network, called this tool the "Ecological Footprint." Essentially, the ecological footprint analyzed the amount of ecologically productive land (measured in ha/capita) required to produce the inputs necessary to sustain the amount of food, housing, transportation, and consumer goods of a given person (in a specific country or settlement), population (number of people in a given country or settlement), human activity (such as logging, driving, sustainable harvesting), or settlement (city, suburb, rural). The following inputs, taken directly from *Our Ecological Footprint*, are considered in determining an ecological footprint (Wackernagel and Rees 1998, 83):

1. Fossil energy consumed expressed in the land area necessary to sequester the corresponding CO_2

2. Degraded land or built-up environment
3. Crop land
4. Gardens for vegetables and fruit production
5. Crop land
6. Pastures for dairy, meat and wool production
7. Forest = prime forest area. An average roundwood harvest of 163 [m^3/ha] every 70 years is assumed

The ecological footprint, the final product of this analysis, measured "the total ecosystem area that is essential to the continued existence" of the person, population, or activity in question (Wackernagel and Rees 1998, 11). This estimation has enabled us to look at the amount of land required to produce the inputs from nature which support typical present consumption in relation to the actual amount of these available resources (Wackernagel and Rees 1998). In their research, Wackernagel and Rees determined that the average ecological footprint of a typical Canadian was 4.3 hectares (approximately 10.6 acres), about equivalent to the area of three city blocks. The ecological footprint of the typical American was about 4-5 hectares (about 9.9 to 12.3 acres). Based on Wackernagel and Rees' estimate that at most, only 1.5 hectares (about 3.7 acres) of productive land exists per person (an estimate that continues to decrease as the population increases), the typical North American consumes three times more than their allotment of natural resources. One of the most influential and widely cited sentences in this book is the authors' proclamation that Canadians and Americans are consuming at a rate that is unsustainable, "if everyone on Earth lived like the average Canadian or American, we would need at least three such planets to live sustainably" (Wackernagel and Rees 1996, 13).

Cities, the authors found, are also among the greatest offenders for having ecological footprints that far exceed the number of hectares of ecologically productive land within their boundaries. If cities were suddenly to become enclosed at their periphery, cut off from the outside world on which they depend, and forced to sustain themselves, Wackernagel and Rees note that:

> [S]uch a city would cease to function and its inhabitants would perish within a few days. The population and the economy contained by the capsule would have been cut off from vital resources and essential waste sinks, leaving it to both starve and to suffocate at the same time (Wackenagel and Rees 1996, 9-10).

Though all of the world's modern cities depend on ecological goods and services provided by places outside of the city which often exceed the land area of the city itself, a city that can provide for itself and have an ecological footprint of 0 is not out of the question (Wackernagel and Rees 1998). In order to achieve such a city, according to Wackernagel and Rees, consumption must invariably decrease, particularly in developed nations. Creative policies, design strategies, a supportive voting population, and an economy that places the highest value on ecosystem vitality would also be necessary. Outlining a city's inability to provide for itself, illustrating urban populations as vulnerable, and creating a way to measure the consumption of a city which could be universally applied to other cities and settlement patterns (suburban and rural) internationally, were among the most influential applications of the ecological footprint. Decreasing the ecological footprint of urban development became and continues to be a goal for planning for urban sustainability and resiliency internationally. This goal has been the foundation for urban policy which encourages smart growth, new urbanism, transit-oriented developments, and other green building initiatives within the urban environment. The carbon footprint (to be discussed later in this chapter) developed by the Global Footprint Network has been more universally applied to human settlement and development in recent years, and used as an argument to encourage urban development over suburban and rural development.

Also significant was Wackernagel and Rees' argument that the ecological footprint provided a foundation upon which to build a new economy: one which recognizes the real ecological constraints on development and material consumption. At the time *Our Ecological Footprint* was published, "the 20 percent of the world's population that lived in wealthy countries were consuming 80 percent of the world's resources" (Wackernagel and Rees 1998, 149). Translating this consumption into ecological footprints, Wackernagel and Rees were able to show that most of these "wealthiest" nations were operating at an ecological deficit. That is, they were consuming at a rate which required more productive land than existed within their borders. Austria, Belgium, Britain, Denmark, France, Germany, the Netherlands, and Switzerland all had Ecological Footprints between 3-4 hectares (about 7.5 to 10 acres) per capita and possessed less than one hectare (about 2.5 acres) of ecologically productive land per capita. The ecological deficits of these countries were significant, ranging from 250 percent to 1,900 percent (Wackernagel and Rees 1998). To support global consumption at these rates without ecological depletion would require Earth to be 30 percent larger (Wackernagel and Rees 1998). As the ecological footprint analysis revealed, the overconsumption observed in the wealthiest of nations is unsustainable, as it cannot be supported indefinitely. For continued human existence with a high quality of life, consistent with the Brundtland Commission's definition of sustainable development, Rees and Wackernagel concluded that current consumption patterns, economic growth, population settlement patterns, and the policies and societal values that dictate these patterns will need to change and become more reflective of what is ecologically realistic.

Shortly after *Our Ecological Footprint*, another highly influential book, *Nature's Services*, was published. This book provided a classification for and further information about the natural resources required to sustain human populations and activities. *Nature's*

Services was composed of twenty essays from contributing authors covering a wide breadth of issues surrounding natural resource consumption. Issues written about included the valuation of natural resources, the hierarchy of natural resources most important to human life, the ecological functioning of and resources provided by various biomes, and case studies about revitalized significant ecosystems. The editor of the book, Gretchen Daily, a biologist and professor of environmental science at Stanford University, called these natural resource inputs "ecosystem services."

In the Introduction of *Nature's Services*, Daily defines ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily 1997, 3). Daily then argues that ecosystem services not only supply the inputs which enable us to produce the goods and services upon which our economy is built, but also carry out the very actions which enable life to exist—cleaning, recycling, and renewing—while acting as the foundation for aesthetic beauty and culture which strengthen human quality of life (Daily 1997). Ecosystem services, as listed in the book, specifically include (Daily 1997, 3-4):

- Purification of air and water
- Mitigation of floods and droughts
- Detoxification and decomposition of wastes
- Generation and renewal of soil and fertility
- Pollination of crops and natural vegetation
- Control of the vast majority of potential agricultural pests
- Dispersal of seeds and translocation of nutrients
- Maintenance of biodiversity, from which humanity has derived key elements of its agricultural, medicinal, and industrial enterprise
- Protection from the sun's harmful ultraviolet rays
- Partial stabilization of climate

- Moderation of temperature extremes and the force of winds and waves
- Support of diverse human cultures
- Providing aesthetic beauty and intellectual stimulation that lift the human spirit

The primary goal of this book was to bring attention to these essential, threatened services, which, as Daily writes, "[f]or millennia, humanity has drawn benefits from…without causing global disruption" (Daily 1997, 5). By discovering a way to classify ecosystem services and providing more information about the science of and human impacts on these essential services, Daily hoped that *Nature's Services* would be used to encourage, strengthen and create new global environmental policy and institutions to minimize the human impact on ecosystem services. "It is at these policy frontiers," Daily wrote, "that lie the brightest prospects for resolving the human predicament and converting the world's societies to new and sustainable resource management regimes" (Daily 1997, 9).

Though *Nature's Services* provided the foundation upon which to build future research on ecosystem services, Daily deliberately avoided the immensely difficult and important task of assigning a monetary value to ecosystem services. A few months after the publication of *Nature's Services*, contributing author Robert Costanza, Director of the Institute for Sustainable Solutions at Portland State University, whose work is focused in ecological economics, published a paper in the journal *Nature*, with several other authors, titled "The Value of the World's Ecosystem Services and Natural Capital." In the article, the authors provide the simplified definition of ecosystem services stated in the first paragraph of this thesis: "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997, 253). Unlike Daily's book, the article was presented as an economic study. However, the message was similar: the authors were attempting to classify and provide a valuation method for the services provided by healthy natural ecosystems, so often undervalued and underweighted in policy decisions, but necessary to sustain human life.

The ecosystem services identified in the *Nature* article were more comprehensive than those provided by Daily. Ecosystem services were identified in the following 17 major categories (Costanza et al. 1997):

1. Gas regulation
2. Climate regulation
3. Disturbance regulation
4. Water regulation
5. Water supply
6. Erosion control and sediment retention
7. Soil formation
8. Nutrient cycling
9. Waste treatment
10. Pollination
11. Biological control
12. Refugia
13. Food production
14. Raw materials
15. Genetic resources
16. Recreation
17. Cultural

To further elaborate, examples of ecosystem services identified by the authors under "disturbance regulation" were "storm protection, flood control, drought recovery, and other aspects of habitat response to environmental variability mainly controlled by vegetation structure" (Costanza et al. 1997, 254).

From original calculations and other published information, the authors were able to roughly estimate the minimum cumulative value of these 17 ecosystem services at $16-$54 trillion a year (Costanza et al. 1997). To put this into perspective, at the time of the study, global GNP (Gross National Product) was about $18 trillion a year (Costanza et al. 1997). The authors concluded with suggestions on how global policy, particularly systems of national accounting, and processes of cost-benefit analyses, might be adjusted to take into account the detrimental social costs that arise from the degradation of these undervalued and vital services. Placing the value of ecosystem services in the context of GNP was an effective tool which garnered worldwide attention. Although many scientists and environmentalists had emphasized the significance of what Daily classified as ecosystem services, no one previously had determined the economic value of these resources. The fact that the potential value of ecosystem services annually, at the lowest estimate, fell just below global GNP, was a figure that could not be ignored. Economically, ecological losses could catastrophic, and gains great successes.

Number	Ecosystem service*	Ecosystem functions	Examples
1	Gas regulation	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Greenhouse gas regulation, DMS production affecting cloud formation.
3	Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	Water regulation	Regulation of hydrological flows.	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation.
5	Water supply	Storage and retention of water.	Provisioning of water by watersheds, reservoirs and aquifers.
6	Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands.
7	Soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen fixation, N, P and other elemental or nutrient cycles.
9	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	Pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	Biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	Refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds.
13	Food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing.
14	Raw materials	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel or fodder.
15	Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	Recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	Cultural	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

* We include ecosystem 'goods' along with ecosystem services.

Table 1: Ecosystem Services used in the Costanza et al. study published in *Nature* (Costanza et al. 1997, 254)

The timing for the introduction and valuation of ecosystem services, from an environmental perspective, could not have been more ideal. Species extinction, disappearing rain forests, polluted water, threats of oil and water exhaustion, and, most significantly, climate change, were some of the globally acknowledged environmental concerns during the late 1990s. On the brink of the new millennium, people were open to new ideas about how to fulfill the ideals expressed in the Brundtland Report's definition of sustainability—that is, to preserve the planet's natural resources for the consumption and enjoyment of future generations. The new millennium marked a significant time in human history; it was as appropriate a moment as ever to make historical changes in human habits. Such actions could ensure the survival of the human species.

Costanza's article in *Nature* received interest from a variety of other disciplines outside economics and the natural sciences. Since its publication, the concept of ecosystem services has permeated the discussions and practices of engineering, medicine, business, design, architecture, landscape architecture, natural sciences, and natural resource management. Our understanding of ecosystem services and their relationship to human environments has increased significantly since their conceptual introduction in the late 1990s. Since this time, it has become apparent just how vital integrating the concept of ecosystem services into the design disciplines.

A significant amount of research has been conducted during the early 21st century, in response to primarily human-induced climate change. This research has examined the relationship between the built and natural environments. *Architecture 2030*, a non-profit organization devoted to reducing the impact of the building sector on climate change and the natural environment, concluded from a report issued by the U.S. Energy Information Administration that buildings in the United States are responsible for "48% of all energy consumption and [greenhouse gas] GHG emissions annually" (Architecture 2030 2011). In addition, they determined that, "globally [this] percentage is even greater" (Architecture 2030 2011). Life-cycle analysis, which measures the environmental impacts of buildings, products, and infrastructure from cradle-to-grave, of revealed that a large portion of this energy consumption comes from poor design (McDonough and Braungart 2002). Buildings, consumer products, and infrastructure are not built to last forever, in order to accommodate the changing and dynamic nature of people and places. The necessary inputs, waste, and energy associated with the extraction, production, and disposal of these inputs are not only one of the greatest contributors of global greenhouse gas emissions, but also significantly disrupt ecosystems and the quality of ecosystem services. The strategic geographic way in which buildings and infrastructure are placed, a facet of planning, also has a significant impact on greenhouse gas emissions and ecosystem services.

At present, civilization faces the great challenge of moving towards sustainable existence amidst a growing population and deteriorating natural environment. The ecosystem services provided by nature, on which human welfare depends, are rapidly declining in quality and quantity, particularly within the urban environment (Costanza et al. 1997). For example, it is becoming more energy intensive and costly to maintain clean air, clean water, and even to provide food in many places in the world. Significant opportunity exists to integrate the concept of ecosystem services in to the design disciplines which both plan the infrastructure, and influence the policies of the built environment. With this integration, these disciplines—architecture, landscape architecture, civil engineering, planning, and policy making—have the power to design and plan in a way which enhances urban ecosystem services. Because the majority of human settlement is now urban, the need to address how human systems may interact symbiotically, or even to enhance ecosystem services has never been more pressing (United Nations Population Fund 2007). Urban planning, the practice by which the many systems of cities are strategically integrated, thereby protecting the public health, safety, and welfare, has the potential to maintain and even enhance the quality and quantity of ecosystem services. This can be accomplished by integrating the goal of optimizing ecosystem services as a principle of practice.

Ecosystem Services and Urban Planning for Sustainability—The Case for TODs

Of the design disciplines, urban planning has been rather late to adopt the concept of ecosystem services into its language and methods of design and practice. Indeed, environmental planning, for years, has been creating policy which regulates individual ecosystem services such as clean air, clean water, endangered species protection, and more recently, CO2 emissions, though without explicitly using this language. As significant and effective as these various environmental policies have been, they are instances of "sustainability fragmentation," in which various policies are working independently and uncoordinated with one another, ultimately towards the same goal of sustainability (Windhager et al. 2010).

As urban populations increase, the challenge of creating environments that are able to provide quality ecosystem services to growing and concentrated populations is urgent. Influential agencies all over the world are establishing the connection between ecosystem services and urban planning. For example, the influential 2005 Millennium Ecosystem Assessment, *Ecosystems and Human Well-Being*, a report published by the World Health Organization and used as the contemporary guide to classifying ecosystem services, presents urban planning as a mitigation and adaptation strategy to reduce the current and potential future risks to human health from the depletion of these services. The report states:

> In order to protect human health, responses very often must involve actions outside of the health sector—particularly in agriculture, industry, education, coastal zone management and urban planning (Millennium Ecosystem Assessment 2005, 9)

The integration of ecosystem services into the study and practice of urban planning is essential to an environmentally sustainable future. The American Institute of

Certified Planners (AICP), the standard professional certification for urban planners in the United States, has begun to incorporate questions about the benefits of ecosystem services on the exam for environmental planner certification. However, questions of this sort have yet to become recognized as appropriate for general certification (AICP 2011). For planners, considering how ecosystem services might be affected by each facet of a project is not a standard of practice, nor is it required by any major environmental policies which regulate the urban environment (Ruhl et al. 2007). For planning academics, students, and practitioners who would like to learn more about the relationship between ecosystem services and urban planning, there is currently little research that establishes any connection between urban planning and how the decisions made by planners may impact the quality and quantity of urban ecosystem services.

In response to the current unprecedented worldwide urban growth, new methods of planning for sustainable urban development have emerged, primarily as mitigation and adaptation strategies in response to climate change and environmental degradation. The Millennium Ecosystem Assessment, in *Ecosystems and Human Well-Being*, provides good definitions for "mitigation" and "adaptation." In the report, adaptation is defined as the action which:

> aims to increase the resilience of both social systems and ecosystems to the impacts of ecosystem change in order to reduce the current and future health risks-and to take advantage of beneficial consequence of ecosystem changes" (Millenium Ecosystem Assessment 2005, 9)

Mitigation is defined as an action which aims to reduce or reverse a change (Millennium Ecosystem Assessment 2005).

The proposed new sustainable planning methods provide the greatest opportunity for the integration of ecosystem services into urban planning. Presently, despite the climatic and environmental emphasis of these various urban design and planning strategies, there is little discussion of ecosystem services in project guidelines and designs (the exception is SITES[1], and only a few comprehensive plans, discussed later in this chapter). Integrating ecosystem services into the design and development of sustainable planning methods can eliminate the lack of cohesion and loss of opportunity for optimizing the quality and quantity of ecosystem services within the urban environment, which occurs without this emphasis.

Transit-oriented development (TOD), a planning strategy which emerged in tandem with Smart Growth, encourages sustainable growth and planning. At present, TOD is a widely adopted planning method by city leaders seeking to improve urban environmental quality. Essentially, a TOD is a compact community that surrounds a transit center (Calthorpe 1993). A TOD is pedestrian-friendly, and offers many building uses and transit options that encourage residents, commuters, and visitors to minimize personal vehicle use, and maximize pedestrian activity and use of civic spaces (Calthorpe 1993). There is also a strong environmental quality preservation goal within TOD planning. The preservation of sensitive habitat, increased building density, encouraging use of civic spaces, and the reduction of personal vehicle miles traveled (VMTs), though not explicitly stated, each contribute to an overall increase in the quality and quantity of local, regional, and global ecosystem services. This emphasis on the preservation of local and regional environmental quality, where the effect on ecosystem services at all scales easily can be observed, makes TOD an ideal candidate to explore how ecosystem services are and can further be incorporated into sustainable urban planning practice. For example, any one TOD has the potential to positively affect at least the following ecosystem

[1] SITES is short for the Sustainable Sites Initiative, a voluntary landscape performance rating system which promotes sustainable landscape design and practices. Further defined and discussed in the "Emerging Methods" section of this chapter.

services: increasing availability and quality of fresh water, decreasing fuel consumption, nutrient and waste management, and cultural and recreational services (Millennium Ecosystem Assessment 2005).

Determining how ecosystem services are currently incorporated into planning methods for sustainability—specifically TOD planning—is only part of this thesis. For this information to be useful, it must be determined *how* the present qualitative values of ecosystem services can translate into policy which encourages further integration of ecosystem services into the design and development of TODs and other planning methods. To determine how further policy might be created that will support this integration, it is necessary to explore the historical development of the policies which have supported this integration in the past. The following section of this literature review provides a brief history of urban environmental policy which has separately and selectively regulated ecosystem services and particularly how the four distinct ecosystem services which TODs most predominantly directly effect have been previously regulated.

TRANSIT ORIENTED DEVELOPMENT'S FOUR ECOSYSTEM SERVICES: A BRIEF HISTORY OF URBAN PLANNING AND URBAN ENVIRONMENTAL REGULATION

The Millennium Ecosystem Assessment established that ecosystem services are essential to global human health and recognized that maintaining and enhancing their health is essential as we face unprecedented growth and economic development. This study refined the classification of ecosystem services from the 17 categories provided by Costanza and his collaborators into the following nine categories (Millennium Ecosystem Assessment 2005):

1. Fresh water.
2. Food.
3. Timber, fibre and fuel.

4. Biological products.
5. Nutrient and waste management.
6. Processing and detoxification.
7. Regulation of infectious disease.
8. Cultural, spiritual and recreational services.
9. Climate regulation.

Of these nine ecosystem services, the four which Calthorpe's Model of TOD planning can and most commonly do address through design and development (slightly transformed from those ecosystem services listed above to fit Calthorpe's TOD model) are:

1. Climate regulation (local and global).
2. Fuel.
3. Processing and detoxification (urban hydrology and urban air quality).
4. Open space, habitat preservation, and recreational services.

These are the primary four ecosystem services discussed in this thesis and explored in this section.

A General History of American Urban Planning and Urban Environmental History

The American Planning Association (APA) provides a good definition of planning:

> [A] dynamic profession that works to improve the welfare of people and their communities by creating more convenient, equitable, healthful, efficient, and attractive places for present and future generations (American Planning Association 2011)

Urban planning is the application of these ideals in a metropolitan setting, thereby protecting public health, safety, and welfare. In 2010 the U.S. Census Bureau identified two types of urban areas (U.S. Census Bureau 2010):

- An Urbanized Area (UA) consists of central and adjacent territories with a cumulative population of at least 50,000 people at a density of at least 1,000 people per square mile (about 2.6 kilometers).
- An Urban Cluster (UC) is classified as central and adjacent territories with a cumulative population between 2,500 and 50,000 people at a density of at least 1,000 people per square mile (about 2.6 square kilometers).

Though evidence of urban planning dates back to the fourth century B.C. with Hippodamus of Miletus' design to rebuild and accommodate 10,000 people in Athen's port town, Pireaus, urban planning in the modern sense, arose in industrial Europe during the late 19th century (Burns 1976; Michael 2005). During this time, urban populations grew significantly. Due predominantly to opportunities for work and higher wages, people were attracted to the urban core, where industry generally was located (Michael 2005). By the end of the century, populations in London and Paris had surpassed one million, and many other cities in both Europe and North America had large populations ranging from 100,000 to 500,000 people (Michael 2005).

The increase of industry and population growth in urban centers, in the absence of planning for the cohesion of the variety of urban uses, led to chaotic and unsanitary cities; they became epicenters of slums and disease (Duxbury 2009). During the early 1800s, urban conditions were so grim that a quarter of Boston's well water was not potable, and New York City's public water was refused by horses (Gale Encyclopedia of U.S. History 2012). Towards the end of the 1800s, waterborne diseases such as typhoid and cholera (linked to human waste in the water supply towards the end of the 1800s) and severe air pollution were rampant in large cities. The English poet John Ruskin wrote his observations of the industrial city in a letter in 1880:

> …the great cities of the earth…have become…loathsome centres of fornication and covetousness—the smoke of their sin going up into the face of heaven like the furnace of Sodom; and the pollution of it rotting and raging the bones and the souls of the peasant people round them, as if they were each a volcano whose ashes broke out In blains upon man and upon beast (Hall 2002, 13)

With the wide publicity of such terrible conditions within cities, the U.S. federal government began to respond with policies to protect the urban public's health, safety, and welfare. While local environmental regulations in the U.S. date back to the mid-17th century, the first federal environmental policy that regulated urban industrial activity was the Rivers and Harbors Act of 1899, and the subsequent Refuse Act of 1899 (which consisted of three sections from the Rivers and Harbors Act) (Williams and Wilkins Co. 1972). The Refuse Act of 1899 banned the dumping of "refuse matter of any kind or description" in any of the United States' navigable water, or tributaries of navigable water, to prevent obstructions (U.S. Senate Committee on Environment & Public Works 1899). Though pollutants flowing "from streets and sewers and passing therefrom in a liquid state" were excepted from this legislation, dumping of "commercial valuable oil, organic settleable solids, cyanides, phenols, sulfides, and ammonia" constituted a federal offense (Williams and Wilkins Co. 1972, 367)

A number of federal environmental regulations and environmental organizations (both governmental and non-governmental) were created in the early to mid-20th century.[2]

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[2] These environmental regulations and organizations included: the Lacy Act of 1900, which protected plants and wildlife; the founding of the National Audubon Society in 1905, which promoted wildlife conservation; the development of the U.S. Forest Service also in 1905; the Weeks Act of 1911, which provided further protection for watersheds and the flow of waters in navigable streams; the Migratory Bird Act of 1913, which regulated hunting and protected migratory birds; the Organic Act of 1916, which saw to the conservation of American natural scenery and land through preservation of unimpaired land and the creation of the U.S. National Park Service; the founding of the Wilderness Society in 1935, the Soil Conservation Society in 1944, and the Nature Conservancy in 1951. The Sierra Club, also a significant environmental organization, was founded prior to 1900, in 1892.

It was not until around the 1960s, however, that environmental policies that regulated distinct ecosystem services significantly impacted the urban environment (Kovarik 2011).

During the early 1960s, academics, scientists, and environmentalists all began publishing about the widespread environmental degradation occurring as the result of increased human development and activity. Of the work published during this time, Rachel Carson's 1962 book, *Silent Spring*, is most commonly cited as the catalyst for the environmental movement; an era which led to the creation a number of influential urban environmental regulations and organizations (Silveira 2004). In her book, Carson established the connection between pollution from synthetic chemicals and decreasing migrating bird populations, illustrating the danger to environmental and public health posed by the use of everyday chemicals like DDT and other pesticides (Carson 1962).

The environmental movement was "grassroots," composed of a number of environmental activists and activist groups who joined forces to uphold the beliefs widely expressed by their predecessors, the early environmental theorists John Muir, Gifford Pinchot, and Aldo Leopold. These early theorists had written of the importance of the natural environment to the human condition, and of the devastation that ensues when land is not properly managed (Leopold 1949). The negative results of widespread economic development—mass species extinction, the 1969 event in which the Cuyahoga River in Cleveland caught fire, increasingly threatened ecologically productive and culturally significant land, and increases in smog and poor air quality in major cities around the country, to name a few—lead these modern environmental advocates to demand better environmental policies and regulations to prevent further environmental and ecological degradation, and to repair the harm that had already been done to these vital natural systems (the political atmosphere at this time was conducive to activism) (Silveira 2004). During this period, often referred to as the "environmental decade," and regarded as the most significant period of environmental progression to date, the following enduring environmental laws, organizations, and events (which essentially regulate and campaign for the preservation and enhancement of distinct ecosystem services) came into existence:

- National Environmental Policy Act of 1969 (NEPA), which established the Council on Environmental Quality (CEQ) and mandatory Environmental Impact Statements
- Environmental Protection Agency (EPA) (1970)
- Earth Day (April 22, 1970)
- Clean Air Act (1970)
- Clean Water Act (1972)
- Coastal Zone Management Act (1972)
- Endangered Species Act (1973)

Since their inception, the policies mandated by these laws and organizations, which are enforced both at state and local levels, have been highly influential and effective in regulating environmental quality. They have been particularly valuable in the regulation of ecosystem services within urban environments. It has been documented that the quality of air and water, particularly in cities, has improved since 1970. Because there are strong economic incentives to operate in a way that exploits the natural environment, it seems likely that in the absence of environmental regulations, governments, businesses, and citizens would simply continue to deplete natural resources and degrade the quality of ecosystem services. The benefit of these regulations can also be observed from a monetary standpoint. President Obama recently remarked that though environmental regulations are costly to those who must make changes to work within them, "the benefits of these regulations exceed their costs by billions of dollars" (Obama 2011).

Despite these successful environmental regulations, considerable work still needs to be done to increase the quality of ecosystem services in cities. A few staggering statistics illustrate the current poor quality of vital ecosystem services within American cities:

- Air pollution, which threatens people's ability to breathe and their livelihood, lingers above almost every major American city at unhealthy levels (American Lung Association 2011).
- About one in 17 Americans--more than 18.5 million people—live in cities with year-round, unhealthy levels of particulate pollution (American Lung Association 2011).
- Several pollutants are found at levels in excess of government health regulations in water supplied by some large utility companies (EWG 2009).
- 86 of the 316 contaminants found in drinking water supplied to the public from 2004 to 2009 have been linked to urban areas and sprawl or wastewater treatment plants and polluted runoff (EWG 2009).
- Urban residents in affluent cities account for more than 80 percent of global greenhouse gas emissions (Hoornweg and Gomez 2011).

Though environmental policy advanced significantly throughout the 20th century, regulation of the natural environment remains fragmented. Only individual ecosystem services are regulated, despite the overlap and influence such regulations have on other ecosystem services. Environmental planning, which evolved in the era of environmentalism that took place during the 1960s has helped provide methods by which to overcome this fragmentation. While Carson's *Silent Spring* established the relationship between human development and environmental degradation, planner and landscape architect Ian McHarg, often referred to as the "grandfather of environmental planning," supplied a more ecological approach to planning and development. The map-overlay method, introduced in McHarg's *Design With Nature*, published in 1969, not only identified the detrimental relationship between development and environmental degradation, but also outlined an innovative environmental planning strategy to make this relationship more compatible. For this planning method, individual attributes of a site's ecology, in addition to cultural values, were outlined on distinct transparencies and layered on top of one another to determine which areas, if developed, would present the least burdensome cost to society (McHarg 1969). This influential ecological approach to urban and regional planning has continued to evolve and inform the practices of urban environmental planning, architecture, and landscape architecture.

Though McHarg's method of environmental planning does factor ecosystem services into project design and development, it still approaches planning from a primarily ecocentric perspective, maintaining ecosystems for the ecosystems' sake. Planning which integrates ecosystem services has an inherently anthropocentric outlook. While McHarg's method of environmental planning presents a less fragmented method of viewing a site or region's ecological strengths and weaknesses, it is used as a tool to determine the suitability of a site for development. The method is not commonly applied for developments seeking to design with sensitivity to the site in order to protect and enhance and the area's strong and weak ecosystem services.

The development of a strong method of environmental planning has aided in the integration of ecosystem services into many planning projects, though this is still not the standard. Comprehensive zoning regulations, which were first formally enacted in the United States in 1916 in New York, and the Standard City Planning Enabling Act of 1928, paved the way for comprehensive and regional planning initiatives in the U.S. and abroad. These policies have set the precedent for planning at all scales into the 21st century (Akimoto 2009). Such initiatives have provided planners with a method and rationale to effectively combat the challenges of accommodating increased population growth with limited land and resources, and a sensitive natural environment. These advancements in planning also have given states and local municipalities seeking to achieve environmental sustainability, a larger tool set to use in regulating land uses and activities within their jurisdiction.

The following sections provide a brief summary of the circumstances surrounding environmental policies which contribute to enhancing or maintaining the four ecosystem services—local and global climate regulation, fuel, processing and detoxification, and open space, habitat preservation, and recreational services—which TODs most strongly (potentially) impact. While some of these policies are federal and previously have been mentioned, others have been created at the state and local levels and implemented through some of the tools of planning discussed above. Understanding how various policies that benefit urban ecosystem services have been created and implemented can provide insight into effective ways to generate future environmentally beneficial policies.

Climate Regulation (local and global carbon cycles)

One of the primary arguments for increasing development of TODs is that they aid in the reduction of greenhouse gas emissions by reducing vehicle miles travelled (VMTs) by encouraging increased building density and mix, and use of alterative modes of transit to the personal automobile—walking, bicycling, and public transit. Because transportation accounts for nearly one-third of total greenhouse gas emissions, and household travel comprises about 75 percent of this figure, TODs are often cited as an effective, sustainable planning strategy to be used to mitigate climate change (National

Household Travel Survey 2009). In addition to reducing VMTs, TODs encourage the creation of additional urban greenspace and vegetation, aiding in carbon sequestration.

Though there is a significant amount of uncertainty as to what the true effects of climate change will be, it is generally accepted that if concentrations of greenhouse gases in the atmosphere continue to increase, the average temperature of the earth's surface will increase by 7.2 degrees Fahrenheit (about -13.7 Celsius) by the year 2100 (EPA 2011). A temperature change of this magnitude will have a catastrophic effect on all ecosystem services, as each of the nine ecosystem services identified by the Millennium Ecosystem Assessment (listed above) are highly sensitive to climatic conditions (Millennium Ecosystem Assessment 2005). Rise in the sea level, extreme weather events, decreases in biodiversity, and loss of productive ecosystems, particularly those which supply human populations with food, potable water, the inputs for human-made energy and medicines, have serious implications for human quality of life, and survival (Millennium Ecosystem Assessment 2005).

Despite the importance of minimizing the human impact on climate change, in the United States few policies have been created to regulate the primary greenhouse gases related to human activity: CO2, methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) (EPA 2012). While the Clean Air Act (CAA) regulates emissions from both buildings and vehicles, greenhouse gases, with the exception of nitrogen and sulfur oxides, are not yet regulated (EPA 2012). Though there has been a strong lobby by public interest groups since the Clinton administration and the creation of the Kyoto Protocol to amend the CAA to regulate greenhouse gases, the political climate since the late 1990s has not permitted such regulations (Office of the U.S. Attorney General 2012). In April 2007, the U.S. Supreme Court ruled that greenhouse gasses were "air pollutants" and it was up to the EPA to determine how emissions from automobiles should be regulated. While the time period mandated by law for the EPA to make the necessary regulatory determinations has passed without the required action being taken, the agency, in 2009, did issue an "endangerment finding" which recognized "that the current and projected concentrations of the six key well-mixed greenhouse gasses…in the atmosphere threaten the public health and welfare of current and future generations" (Office of the Attorney General 2012; EPA 2011; see section 202(a) of the Clean Air Act). While this endangerment finding did not lead to an amendment of the CAA, in 2010 the EPA, in partnership with the Department of Transportation's National Highway Traffic Safety Administration (NHTSA), promulgated a rule to increase the Corporate Average Fuel Economy (CAFE) for all new cars and trucks. Starting in 2016, new vehicles will be required to the average 35.5 miles (about 57.2 kilometers) per gallon (Office of the U.S. Attorney General 2012).

While no federal policy to regulate national greenhouse gases has yet been created, a number of states and municipalities are creating enforceable policies of their own, through statewide, countywide, and citywide initiatives and comprehensive plans. California's statewide greenhouse gas regulations have received the most significant attention, as they are among the most progressive policies in the country. These policies include:

- Assembly Bill 32: The Global Warming Solutions Act of 2006 (AB 32) which implemented a state-wide greenhouse gas cap-and-trade program and introduced state greenhouse gas reductions to 1990 emissions levels by December 31, 2011 into law (California Environmental Progtection Agency Air Resources Board 2011).

- Senate Bill 375: The Sustainable Communities and Climate Protection Act of 2008 (SB 375) which links climate change to land use planning and transit types, and through the addition of new specifications under the California Environmental Quality Act, encourages better land use decisions, described as the "Sustainable Communities Strategy," which seeks to reduce greenhouse gas emissions through preserving farmland and open space and promoting mass transit networks and alternative development patterns to reduce sprawl, described as the "Sustainable Communities Strategy" (Adams, Eaken and Notthoff 2009).

A number of states have adopted similar, though less stringent, statewide initiatives. These states include Arizona, Colorado, Connecticut, Florida, Hawaii, Illinois, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, Oregon, Rhode Island, Utah, Vermont, Virginia, and Washington (Royden-Bloom 2008). Regional initiatives that aim to reduce greenhouse gas emissions also have started to emerge, with a number of the states listed above adopting these goals as their own. Regional greenhouse gas reducing initiatives include the Western Climate Initiative, the Midwestern Regional Greenhouse Gas Reduction Accord, and the New England Governors and Eastern Canadian Premiers Climate Change Action Plan 2001 (Royden-Bloom 2008).

Countywide and citywide greenhouse gas reducing plans exist for practically all major cities, and for progressive counties and small towns. Under these carbon reducing plans, states, counties, and smaller municipalities alike are exploring carbon sequestration and VMT reducing programs (discussed in the next section of this chapter) as primary ways to mitigate greenhouse gases. Citywide tree planting programs have become commonplace throughout the country as concern of climate change increases. One example is Albuquerque, New Mexico's Urban Forestry Initiative, which has planted over 15,000 trees within the city limits to remove over 735 tons (about 666, 780.8

kilograms) of carbon dioxide a year (The Home Depot Foundation 2007). State programs like the Georgia Carbon Sequestration Registry, which catalogues the efforts of smaller municipalities within the state, are also gaining in popularity (Georgia Carbon Sequestration Registry n.d.).

Fuel

While TODs aid in the reduction in greenhouse gasses by decreasing VMTs through encouraging use of mass transit, walking, bicycling, and a dense, multitude of diverse commercial, retail, and residential land uses within proximity to transit, they also are simultaneously contributing to reducing human dependence on fossil fuels. Crude oil, or petroleum, is the most relevant of the non-renewable fossil fuels in the context of TODs, since this is the fossil fuel from which gasoline is derived.

Petroleum, from which kerosene, motor gasoline, diesel, lubricating oil, and industrial fuel are produced, is an ecosystem service in that it is the product of the remains of sea flora and fauna, buried under thousands of feet of sand, silt, or mud, and decomposing for millions of years (Freudenrich 2001). The evolution of contemporary culture and technology is the direct result of the availability of petroleum, its products, and the byproducts of these products. The majority of motor vehicles, machinery, and tools to support technological innovation, as they are designed now, cannot operate without fuels produced from petroleum. In some cases, other, more plentiful, non-renewable fuel sources, such as natural gas and coal, can be substituted for fuel from petroleum. However, even the infrastructure necessary to extract, refine, and create energy from non-petroleum fuel sources is dependent on petroleum products. For example, most systems which supply large populations with water, heat, and electricity, require motor fuel, diesel, lubricating oil, and industrial fuel for infrastructure construction and operation.

As the global population continues to increase, so does the demand and consumption of petroleum, its products, and its byproducts—particularly gasoline, diesel, kerosene, industrial fuel, and plastics. Increased demand and consumption of petroleum continues to place greater strain on the environment's natural regulatory systems. Extraction destroys habitat, landscapes, and contaminates groundwater supply, while consumption degrades air quality and contributes to global warming. Presently, uncertainty exists in the United States as to how much longer the global supply of petroleum will be able to meet this growing demand. Globally, oil production has not grown since 2005, which suggests that this was the year in which global oil extraction peaked. While some argue that a number of variables skewed these oil supply data and that "peak oil" production has yet to occur, others believe in "peak oil" and see the lack of growth in global oil production as the beginning of a rapid decline in oil supply, giving us about a century to switch completely to new alternatives (Micu 2010). Many, however, find the discussion of peak oil production irrelevant, and look at the facts: half of the world's oil supply has yet to be consumed, and the world supply of non-conventional energy resources—such as wind, solar, tidal, nuclear, hydrogen, and shale oil—is still quite large (Micu 2010).

Despite uncertainties as to when oil shortages will occur, there is a general consensus that petroleum is not environmentally or economically sustainable. Extraction and consumption of petroleum contributes to habitat destruction, degraded air and water quality, and climate change. While remediation of these environmental issues is and will continue to be a costly endeavor, it is also clearly understood that at some point in the future, petroleum itself will not be as easily extractable, and fuel costs will skyrocket. For these reasons, in addition to concerns about fuel security, and international policy, there is a general consensus that we, as a society, must begin to reduce our dependency on fossil fuels, and transition to economically and environmentally sustainable fuel sources (Millennium Ecosystem Assessment 2005).

In recent years, the federal government has begun to implement policies like reducing fuel CAFE standards (see previous section), and providing renewable energy tax credits, which reduce fuel and energy consumption through encouraging use of more efficient and environmentally friendly technologies. While a number of states and municipalities have followed suit and begun offering local incentives to reduce energy consumption, many local jurisdictions are starting to understand that reducing fuel dependency will require not just better technology, but changes in habit. All over the country, local governments are designing and implementing creative policies to encourage people to use alternative modes of transit to the automobile, in hopes of reducing overall VMTs, and thus fuel consumption. These local jurisdictions, which have to deal with less political red tape than is common at state and federal levels, have been very successful in creating infrastructure to achieve goals of reducing fuel consumption.

Since 2000, regional rail and light rail systems, system extensions, and streetcars have been either proposed and or implemented in large U.S. cities including Albuquerque, Atlanta, Austin, Birmingham, Cincinnati, Columbus, Dallas, Honolulu, Jacksonville, Milwaukee, Minneapolis, Nashville, New York, Orlando, Phoenix, Seattle, Tampa, and Washington D.C. (Light Rail Now 2007). In the past few years, car sharing programs also have become increasingly popular as alternatives to the automobile. Sponsored by either cities or private entities, these programs provide vehicles for short-term or as-needed rentals at a small membership fee that covers the cost of insurance and car maintenance. Car sharing programs can be found in almost all major U.S. cities.

According to one study on car sharing patterns, "[a]s of July, 2011, 26 U.S. car sharing programs claimed 560,572 members sharing 10,019 vehicles" (Innovative Mobility 2012).

With better public transportation opportunities, cities are becoming more relaxed on minimum parking requirements. Starting in 2005, for example, San Francisco, where parking requirements have existed since 1955, has been adopting various neighborhood plans around the city which have no parking requirements. The downtown parking reform passed in the city in 2006 was especially significant in that it eliminated parking minimums for housing units in the downtown commercial districts. This reform also set the lowest residential parking maximums the city had ever seen, less than one parking space per residential unit (Livable City n.d.).

Reduced parking regulations have been helpful in increasing more pedestrian and bicycle friendly streets. Less dedicated on-street parking leaves room for dedicated bike lanes, wider sidewalks for high volume pedestrian areas, and space for more street trees, planter boxes, and benches. Creating more pedestrian and cyclist friendly streets has been a high priority for local municipalities within the past five years. During this time, most major cities have created master bicycle plans, increased the safety and connectivity of bike lanes, and created education programs for employers to encourage cycling to and from the workplace. The Baltimore Metropolitan Council (BMC), Maryland, is one of many U.S. municipalities to provide local employers with an "Employer Guide to Bicycle Commuting" booklet which contains information about the cost savings for employers associated with employee bicycle commuting, and ways to encourage bicycle commuting in the workplace (BMC et al.). Road diet and street beautification programs have also been implemented in cities across the country in recent years to encourage walking and to ensure pedestrian safety.

There are few federal and state level policies that promote change in commuting habits and significantly reduce fuel consumption. At this level, it is incredibly difficult to implement policies which greatly impact everyday habit. Widespread adoption of fuel taxes and carpool lanes, are two highly effective ways to encourage reduction of fuel consumption, but are politically difficult to implement. At the local level, low-emissions zones (LEZs), which are commonly used in Europe and ban heavy-polluting vehicles from specified roads or areas, also would be highly effective to encourage use of alternative modes of transit. LEZs have not yet been implemented in the U.S., most likely because they are not politically palatable.

Processing and Detoxification (air and hydrologic cycle)

Air Quality

The ecosystem service of "processing and detoxification" refers to the natural purification provided by ecosystems in the "recycling and redistribution of nutrients" (Millennium Ecosystem Assessment 2005, 4). In the urban environment, processing and detoxification refers primarily to the air and water cycles. The combustion of fossil fuels from transportation accounts for a large portion of outdoor air pollution (Millennium Ecosystem Assessment 2005). Similarly, vehicles leach inorganic chemicals onto roads. Without proper green infrastructure, rain washes away these chemicals untreated into local water bodies that feed into a greater watershed. Untreated stormwater runoff can contaminate drinking water, groundwater, and sensitive habitats. By reducing vehicle travel and fuel consumption, and encouraging additional greenspace and the use of natural retention systems to improve stormwater quality and management, TODs significantly aid in the processing and detoxification of polluted urban air and water, therefore improving the quality of these resources.

Air quality is an ecosystem service that is strongly regulated by the federal government. The regulation of air quality began with the Air Pollution Control Act of 1955, which provided federal funding for air pollution research (EPA 2012). The initial Clean Air Act (CAA) introduced in 1963, and was the first federal law which sought to control air pollution. Under this law, a branch of the U.S. Public Health Service was created to research methods to monitor and control air pollution (EPA 2012). In 1967, the Air Quality Act was created, under which the federal government initiated a series of enforcement proceedings regarding the transport of interstate air pollution. As a result of, the federal government conducted research regarding air pollution emissions, air quality, and air pollution monitoring (EPA 2012).

The CAA of 1970 remains the most influential law passed to regulate air pollution in the U.S. This act gave the government the power to create regulations relating to emissions from mobile and stationary pollution emitters, at both the federal and state level. The U.S. EPA, created as a result of NEPA also in 1970, became the agency chosen to implement the CAA (EPA 2012). Since 1970, there have been two major amendments to the CAA, the first in 1977, and the most significant and most recent in 1990. The 1990 Amendments expanded the list of regulated pollutants to include chemicals that contribute to acid deposition (acid rain), like nitrogen dioxide and sulfur dioxide, and chemicals that deplete the ozone layer, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) (EPA 2012).

The cost of implementing the proposed additional and more stringent regulations outlined in the 1990 CAA Amendments is estimated to be about $65 billion in total. However, the direct benefits of these regulations far exceed the costs and are expected to be about $2 trillion in the year 2020. This $2 trillion estimation is calculated from the reductions of adult and infant mortality related to less particulate matter and ozone in ambient air (see Table 2 below) (Office of Air and Radiation 2011).

Health Effect Reductions (PM2.5 & Ozone Only)	Pollutant(s)	Year 2010	Year 2020
PM2.5 Adult Mortality	PM	160,000	230,000
PM2.5 Infant Mortality	PM	230	280
Ozone Mortality	Ozone	4,300	7,100
Chronic Bronchitis	PM	54,000	75,000
Acute Bronchitis	PM	130,000	180,000
Acute Myocardial Infarction	PM	130,000	200,000
Asthma Exacerbation	PM	1,700,000	2,400,000
Hospital Admissions	PM, Ozone	86,000	135,000
Emergency Room Visits	PM, Ozone	86,000	120,000
Restricted Activity Days	PM, Ozone	84,000,000	110,000,000
School Loss Days	Ozone	3,200,000	5,400,000
Lost Work Days	PM	13,000,000	17,000,000

Table 2: The benefits associated with reduced particulate matter and ozone in ambient air (Office of Air and Radiation 2011, 13)

In addition to federal air quality regulations, beginning in the 1990s state governments adopted statewide clean air acts to further regulate the air quality within their jurisdictions. Of these statewide acts, the California Clean Air Act remains the most comprehensive. The State of California requires lower concentrations of pollutants in air than are allowed by the federal government, and regulates the following additional pollutants for which no federal standards exist (Air and Resources Board 2012):

- Visibility Reducing Particles
- Sulfates

- Hydrogen Sulfide
- Vinyl Chloride

Throughout the nation, business owners, municipalities, and citizens have adjusted to statewide and local policies which support the air quality standards stipulated by federal and state governments. A number of states, including Texas and Michigan, have implemented emissions trading programs to meet the allowed emissions levels for chemicals which cause acid deposition and destroy the ozone layer (TCEQ 2012; DEQ 2012). In California, local jurisdictions like the Bay Area Air Quality Management District have created programs to reduce particulate matter emissions and warn of ground-level ozone, during the winter and summer months, respectively. “Spare the Air Days,” in the Bay Area during the winter months, consist of personal fire bans, and during the summer months, of warnings of smog in the newspaper and on the local radio stations (Spare the Air n.d.).

Car sharing programs, high occupancy vehicle (HOV) lanes (also known as carpool lanes), improvements to mass transit programs, and the introduction of TODs are other common methods which have been explored by cities all over the country to improve local air quality and to meet state and federal standards. Particularly in California, with AB 32 and SB 375, new TODs, and retrofitting communities for TOD, are becoming increasingly popular planning initiatives.

Hydrology

As stated in the introduction of this section, water quality was the first ecosystem service to be regulated by the federal government with the River and Harbor Act of 1899, and the subsequent Refuse Act of 1899. Since the late 20th century, water quality and quantity has been a contentious issue among governments at all levels, leading to more stringent regulations for drinking water, stormwater, and groundwater. Water is among the most vital of ecosystem services. Poor water quality will make people sick, and without water a human being can live for only three to 10 days (Binns 2010).

While the first water quality regulations in the U.S. were introduced at the turn of the 20th century, significant increases in population and industry in the mid-century were accompanied by more comprehensive federal legislation controlling water pollution. The first of these laws was the Federal Water Pollution Control Act of 1948, which established limited federal funding for regulating the water quality of interstate water, tributaries, and surface and groundwater (EPA 2012). This act was closely followed by the Water Quality Act of 1965, which required individual states to set their own water quality standards for interstate waters (EPA 2012). Almost all states had adopted interstate water quality standards by the early 1970s.

During the 1960s and the 1970s, a series of amendments to the Federal Water Pollution Control Act increased the authority of the federal government to enforce water quality standards. The 1966 amendment, referred to as the Clean Water Restoration Act of 1966, mandated research to be conducted about the effects of pollution on U.S. estuaries (FWS n.d.). The amendment of 1970, called the Water Quality Improvement Act, prohibited dumping of oil into U.S. waters unless approved by the President of the United States (FWS n.d.). After 1970, the EPA became the federal agency in charge of monitoring water quality. The 1972 amendment, under which the National Pollutant Discharge Elimination System (NPDES) was created, required all known polluters who discharged into U.S. waters to obtain permits, and mandated that the EPA establish limitations, rooted in scientific reasoning, on the effluent charged per permit (EPA 2012). This amendment also introduced national objectives to maintain the quality of America's water resources (FWS n.d.). The Clean Water Act of 1977, among other laws, required states to develop "best management practices" to control water pollution (FWS n.d.).

The 1980s marked the most significant era for water quality standards. Beginning in 1984, as stipulated in a Clean Water Act amendment, permits for discharge into streams could not be awarded unless the party seeking the permit could provide evidence that their water quality standards were up to date (EPA 2012). The most recent amendments, enacted in 1987, require states to develop a standard for toxic water, identify polluted waters, and create strategies for toxic water cleanup (EPA 2012).

As this brief history of U.S. water quality regulations illustrates, the development of water quality standards and best practices is left to individual states, and the regulation and enforcement of these standards to local municipalities. The state water quality standards most significant to urban environments are the stormwater and groundwater quality standards. Stormwater management has significant implications for urban water quality. As described by the City of Portland, Oregon's Bureau of Environmental Services:

> …stormwater runoff that isn't properly managed can flow over impervious surfaces picking up pollutants along the way and washing them into rivers and streams. Stormwater runoff can also cause flooding and erosion, destroy habitat and contribute to combined sewer overflows (CSOs) (BES 2012)

In addition to these impacts, stormwater that is not properly purified can contaminate groundwater sources. Groundwater is one of the largest and most important sources of freshwater.

To avoid the negative impacts associated with poor stormwater management, most urban areas have developed stormwater management programs. Stormwater management programs outline an area's stormwater plans and existing infrastructure. The function of this infrastructure is to manage stormwater peak flow, volume, and quality.

Impervious zoning regulations, common in most major cities, are vital components to stormwater management plans. Stormwater can be managed either conventionally, using sewer lines and water treatment facilities, or unconventionally, by using "green infrastructure." Green infrastructure refers to the use of natural systems such as bioswales, retention pools, and rain gardens. Areas utilizing green infrastructure commonly require additional permeable surfaces to retain and filter stormwater, thus managing peak flows, volume, and stormwater quality. Increased stormwater quality has beneficial implications for groundwater quality.

In recent years, many urban areas' stormwater plans have been written or adjusted to incorporate green stormwater infrastructure. The City of Portland, for example, initiated an ongoing "Grey to Green" campaign in 2008. This campaign seeks to expand the city's stormwater management infrastructure to include "techniques that mimic natural systems, protect and restore natural areas, and improve watershed health" (BES 2012). TODs, which encourage the use of natural water filtration and permeable surfaces (greenspace and permeable pavers), are a useful planning tool to help cities meet grey to green goals.

Open Space, Recreational Services, and Habitat Preservation

TOD design both creates and preserves open space. The TOD design requirement of a small percentage of site area as greenspace leads to an increase in urban open and greenspace. The compact, infill, medium- to high-density nature of a TOD, ultimately preserves open space, since TODs are often used as alternatives to sprawl. Open space is an ecosystem service which provides both material and non-material benefits. Material benefits of open space include habitat preservation and permeable surfaces, essential to natural stormwater management. Non-material benefits of open space, which increase human physical and mental health and well-being, and overall quality of life, include opportunities for “tourism, recreation, aesthetic appreciation, inspiration, and education” (Millennium Ecosystem Assessment 2005, 5).

In the urban environment, open space, in addition to creating more urban animal habitat, provides essential areas where people can recreate, both passively (walking, picnicing) and actively (running, biking, playing sports). For centuries, philosphers have been writing about the importance of greenspace to human health. Recent studies and empirical evidence have demonstrated that there is in part, some truth to these beliefs. One study, published in the *Journal of Epidemiol Community Health* in 2006, concluded “that the percentage of green space in people’s living environment has a positive association with the perceived general health of residents” (see Figure 1 below for an illustration of this relationship) (Maas et al. 2006, 587).

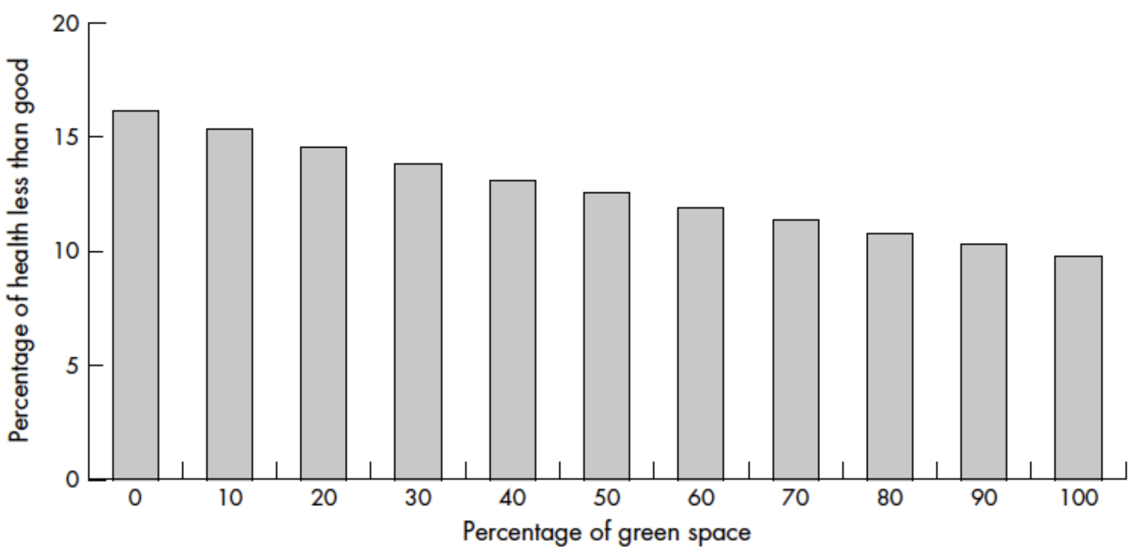

Figure 1: Relationship between the amount of greenspace and perceived health (Maas et al. 2006, 588)

Another study, presented at the American Heart Association Conference in 2009, found that children at risk for obesity who live near parks or recreational areas, are more physically active, thus reducing their chances of obesity early in life (Brunner 2009).

Given the benefits of additional urban greenspace and recreational opportunities to the natural environment and to public health—reduced obesity, ensuring pulmonary health, stress reduction—many cities mandate a certain amount of greenspace per thousand residents. The National Recreation and Park Assocation (NRPA) suggests that for every 1,000 residents, an urban area should have, at minimum, one to two acres (about 0.4 to 0.8 hectares) of neighborhood parks, five to eight acres (about two to three hectares) of community parks, and five to 10 acres (about two to four hectares) of regional parks (UI n.d.). Some cities, like Birmingham, Alabama, exceed this suggested minimun with 17.9 acres (about 7.2 hectares) of greenspace per 1,000 residents. Other cities, like Boston, Massachusettes, struggle to provide at least two acres (about 0.8 hectares) total of greenspace to residents in Central and South End neighborhoods (Birmingham Regional Chamber of Commerce 2010 ; The Boston Indicators Project 2012).

Like Boston, many established areas have difficulty meeting these greenspace standards, as there may be few vacant and adjacent parcels available to create a sizable park. Over the past few years, pocket parks have emerged as creative ways for dense cities to obtain additional open space and greenspace in their central core. While some urban pocket parks are emerging on vacant or underutilized parcels, other pocket parks, like Paley Park, located in the heart of New York City, are privately developed on in demand parcels for the public benefit (PPS n.d.).

Interaction of Ecosystem Services

It should be noted that while the four ecosystem services are divided in this thesis as distinct, most of the policies which enhance each of these ecosystem services, have secondary effects of enhancing other ecosystem services. For example, design strategies and policies that decrease VMTs—such as increasing bike lanes, pedestrian activity, transit options, and providing a mix of land use in a small area—not only have implications for climate regulation, and reduced air pollution and fuel consumption, but also benefit stormwater quality by reducing road surface pollutants from vehicles and increasing demand for pedestrian spaces which may have permeable surfaces. The addition of urban street trees and greenspace have the primary effect of increasing recreational space and urban habitat, and improving stormwater retention and filtration by reducing an area's impervious cover. However, these design strategies also benefit climate regulation through natural carbon sequestration. In the chapters to follow, it is important to recognize that there are multiple positive and negative feedback loops associated with each individual TOD design strategy. That is, each design strategy impacts, both positively and negatively, a wide variety of ecosystem services. When multiple design strategies enhance ecosystem services, as is the case with a TOD, there is a cumulative and beneficial affect.

EMERGING METHODS

While integrating ecosystem services into TOD design and planning is not yet a standard of practice, a number of methods have emerged in recent years which further facilitate this integration. The most notable of these methods is the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED), a green building certification introduced in 2000, which has expanded market demand for energy efficient buildings nationwide. LEED, a rating system, earns a newly constructed or majorly renovated building (commercial, office, or residential) a standard, silver, gold, or platinum certification. The LEED certification awarded depends on the number of points obtained for sustainable building design strategies (platinum is the highest and most difficult certification to achieve).

In 2009, the USGBC, in partnership with the Congress for New Urbanism and the Natural Resources Defense Council, introduced LEED for Neighborhood Development (LEED-ND). LEED-ND is the first national rating system for neighborhood design and awards a LEED standard, silver, gold, or platinum certification to a new or redeveloped neighborhood-scale development. At minimum, a LEED-ND neighborhood must be compact, mixed-use, walkable, contain at least one LEED certified building, and exercise conservation strategies for natural resources within its boundary (USGBC 2009). Additional points are given to neighborhoods that go beyond the minimum LEED-ND certification requirements and integrate more sustainable practices into design and development. Examples of sustainable design strategies that earn a development extra points include: an extensive bicycle network, bicycle storage opportunities, the presence of transit facilities, tree-lined and shaded streets, water efficient landscaping, and the reuse of existing buildings (USGBC 2009). Many LEED-ND developments are also TODs, since the USGBC's certification requirements are similar to several of Calthorpe's TOD design guidelines (at least all or part of the two case studies explored in this thesis are candidates for LEED-ND certification). LEED-ND has become a very popular program because certification can save developers energy costs and provide them with an additional marketing tool to sell or lease their development. Therefore, LEED-ND certification is viewed as providing an additional incentive to build in a way which maintains or enhances local ecosystem services.

While the USGBC does not use the term "ecosystem services" in describing the goals, strategies, or desired outcomes of the various LEED certifications, these programs have influenced a number of other building and planning initiatives that do explicitly identify the enhancement of ecosystem services as primary development or planning goal. The most notable of these programs is the Sustainable Sites Initiative (SITES), a performance-based rating system used to measure the site sustainability of both developed and undeveloped sites. The objective behind the program is to foster "a transformation in land development and management practices that will bring the essential importance of ecosystem services to the forefront" (SITES 2009, 5). Since it was introduced in 2007, SITES has garnered international attention and has, most recently, influenced the preferred sustainable landscape design practices set forth by the White House Council on Environmental Quality (CEQ) (CEQ 2011). *Guidance for Federal Agencies on Sustainable Practices for Designed Landscapes* provides suggestions for the improvement of landscape practices for federal agencies, when "constructing new, or rehabilitating existing, owned or leased facilities or when landscaping improvements are otherwise planned" (CEQ 2011, 4). Making decisions which maximize ecosystem services is one of the primary goals of the landscaping suggestions outlined in this report (CEQ 2011).

The Living Building Challenge, introduced by the International Living Future Institute in 2006, is another popular building initiative which cites the production of ecosystem services as a goal of development (ILBI 2010). The challenge, which has extended beyond the U.S. to Canada, Ireland, Mexico, and Australia, calls for all design professionals, politicians, and government officials, as well as all of humanity, to retrofit the built environment into a place which is in harmony with the natural environment.

Among the most significant of the challenge goals are creating buildings which are carbon and water neutral (ILBI 2010).

Planning with the goal of enhancing ecosystem services is also emerging at local levels. In June 2008, the State of Nevada's Washoe County adopted the *Regional Open Space & Natural Resource Management Plan*, in which the universal goal of the plan strived "for no net loss of these services" (Nelson et al. 2008, 2). "Sustainability and Ecosystem Services" also comprise a section of the plan, which clearly explained the relationship between ecosystem services and Washoe County's planning goals. Cost savings associated with the enhancement of ecosystem services were also outlined in the document (see Figure 2 on the following page for one of the explanatory diagrams from the plan). The new City of Damascus in Oregon, incorporated in 2004, has decided, in its initial stages of city planning, to adopt an ecosystem services planning ethos. In partnership with CH2MHill consultants, the city has "developed a high-level methodology to identify, asses, and quantify natural resource ecosystem services" (CH2M Hill 2010, 1). The city hopes to use this information "to integrate ecosystem service valuation into decision-making processes and develop an equitable system to manage the resources" (CH2M HILL 2010, 1).

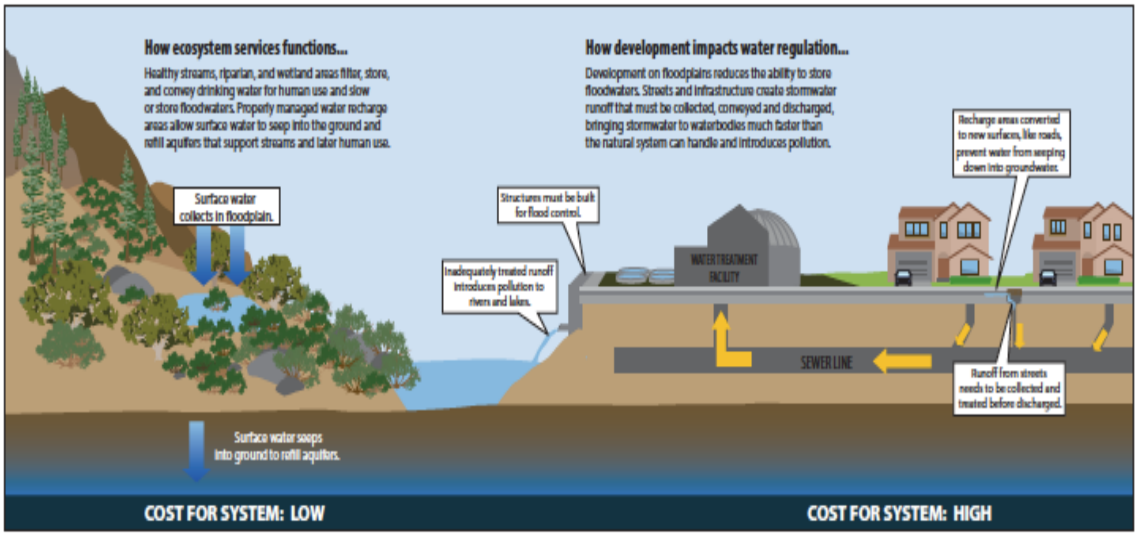

Figure 2: Water Quality and Regulation Ecosystem Service (Nelson et al. 2008, 53)

Advances in technology over the past decade have helped scientists and practitioners to map, value, and analyze local, regional, national, and international ecosystem services. Technological tools such as Geographic Information Systems (GIS) have made it easier to observe, synthesize, and model large amounts of spatial, environmental, and ecosystem services data. Other software like InVEST (Integrated Valuation of Environmental Services and Tradeoffs) and ARIES (ARtifical Intelligence for Ecosystem Services) have simplified the decision making processes surrounding ecosystem services, by analyzing alternatives and using probability modeling (Natural Capital Project 2007; ARIES 2012)

The concept of ecosystem services is also beginning to permeate educational programs, both nationally, and abroad. Portland State University (PSU) in Oregon, is a recent participant in the National Science Foundation's Ecosystem Services for Urbanizing Regions IGERT program, which seeks to "educate U.S. Ph.D. natural and social scientists and engineers beyond their normal disciplinary boundaries to help solve some of the world's most complex problems (ESUR 2012). The University of Edinburgh, in Scotland, offers a Master of Science in Ecosystem Services (School of GeoSciences 2012).

CONCLUSION

Worldwide, people are moving towards urban settlement. In 2008, more than half of the earth's population was living in urban areas, and this share is expected to grow quickly (UNFPA 2007). The UNFPA *State of the World Population 2007* warns of increasing urban populations, "[t]heir future, the future of cities in developing countries, the future of humanity itself, all depend very much on decisions made now in preparation for this growth" (UNFPA 2007, 1). As humanity moves toward an urban civilization, the challenge of creating environmentally sustainable built environments that provide quality ecosystem services to growing and concentrated populations is omnipresent.

This literature review of ecosystem services, planning, and urban environmental policies illustrates the following:

- There is little research which recognizes the relationship between planning and ecosystem services, and no research identifying the relationship between urban planning, TOD, and ecosystem services.
- TOD is a potential mitigation and/or adaptation planning strategy for environmental sustainability.
- TODs enhance the following four ecosystem services: climate regulation; fuel; processing and detoxification; and open space, habitat preservation, and recreational services.
- Significant environmental policies, introduced at the federal level, commonly emerge after periods of intense change and activism.

- Presently, this is a global time of intense change and informed activism.
- While influential policies are introduced at the federal level, innovations which enforce these policies exist at the state and local levels.
- Though ecosystem services are emerging as a useful and effective concept in planning and policy making, instances of the use of this concept remain uncommon in these fields

The following chapters further explore how, in theory and practice, TODs incorporate ecosystem services into design and development, and the policies that facilitate this integration in the urban environment. Through interviews with practitioners, and reviews of plans and TOD design strategies in two case studies, the value of ecosystem services to design professionals—planners, landscape architects, and architects—and policy makers is analyzed. This study concludes with suggestions for future policies that can aid in integrating ecosystem services into TODs and urban planning, and ideas for future research on this subject.

Chapter 2: Method

OVERVIEW

The idea for this thesis arose out of a paper submitted for the graduate planning course called "Environmental Readings," at The University of Texas at Austin. This course required students to write a brief essay about a theory of their own in relation to their area of study. The paper submitted for that course was titled "Planning by Ecosystem Services: Optimizing Ecosystem Services as a Principle of Urban Planning Theory and Practice" and explored the idea of integrating ecosystem services as a cornerstone of planning theory and practice in order to move toward urban environmental sustainability. This thesis is an expanded and more detailed version of that essay. While the original essay explored the idea of integrating ecosystem services into the practice of urban planning and design and development of urban environments, this disciplinary field has been narrowed in this study to the design and development of one particular area of urban planning, TOD. In the previous essay, ecosystem services were referenced as an overall concept, while in this thesis, the individual ecosystem services most affected by TOD are identified and explored in greater depth.

To complete this study, a number of research methods were used. A literature review was completed for a proposal for this thesis, and expanded in this thesis itself. Literature was identified through discussions with professors and practitioners, and extensive review of the content and citations of previous articles published on this topic. The literature review included previous studies involving ecosystem services as they apply to all disciplines, as well as books and articles by academics and practitioners about ecosystem services, TOD, urban environmental policy, and best practices for environmental sustainability. Sources included both governments and non-governmental organizations.

In addition to the literature review, an in-depth analysis of how the design elements of Peter Calthorpe's TOD model, introduced in *The Next American Metropolis*, incorporate the identified ecosystem services was then conducted. Two TOD case studies in the American Northwest were selected next and their design and development analyzed to determine how, and the degree to which, ecosystem services were incorporated into each project. Interviews with planning, architecture, and landscape architecture academics and practitioners, and planners and policy makers in each city who were either familiar with or had personally worked on some aspect of one of the case study projects were then conducted. The data obtained from these interviews, which are discussed in greater detail later in this section, helped to provide answers to the research questions listed at the beginning of this thesis. These data also supplied information about the case studies that has not been published elsewhere, overall contributing to a more in-depth analysis of each case.

THE CASE STUDIES

The two TOD case studies analyzed in this thesis are located in Portland, Oregon, and Seattle, Washington. The method used to analyze each case study is based on the one outlined by Mark Francis in his article, "A Case Study Method for Landscape Architecture," published in *Landscape Journal*. However, for research consistency, the information provided in each case study is somewhat different than what is suggested by Francis. TODs were selected in Portland and Seattle because both places frequently are cited in the literature as cities, in environmentally progressive states, which are at the forefront in the U.S. in creating and implementing innovative policies and mass transit systems to facilitate more environmentally friendly urban planning.

The specific TODs examined in these cities were the Pearl District in Portland and South Lake Union in Seattle. The Pearl District was selected as a case study because it is a mature development, frequently cited as a model of an environmentally progressive American TOD, highly successful in reducing VMTs. It is also one of the most written-about and well documented TODs in the United States. Through discussions with professors and practitioners, South Lake Union was identified and selected as another interesting case study. A large part of South Lake Union, unlike the Pearl District, is still under construction. Despite this, however, it is still considered by many as an up-and-coming TOD, having already attracted several large commercial tenants. With regard to environmental design, South Lake Union has plans to implement a pioneering urban environmental stormwater management system (discussed in greater detail in Chapter 5).

The similarities between these two TODs also made them appealing as case studies for this thesis. Both are located in the Pacific Northwest. Both are examples of infill development. Both are projects which are participating in the USGBC's LEED-ND certification program. Both are neighborhoods that consist of a number of properties with different owners. Finally, both have been continuously evolving since the late 1990s.

Analysis for each case study began by conducting a literature review and obtaining information from interviews about the history, background, design strategies, development, implementation, and policies which influenced the design and development process. After acquiring this information, and reviewing district and neighborhood comprehensive plans and design strategies, the projects were analyzed to determine how the TOD concepts provided by Calthorpe in *The Next American Metropolis* were integrated into project design and development, and how and which ecosystem services were present in neighborhood planning and design. The product of this analysis was used to compose the final section of this thesis, which provides some policy suggestions to further encourage the integration of ecosystem services into the design and development of Urban TODs. While both of these projects vary to some extent from the prototypical TOD design illustrated in *The Next American Metropolis*, they nevertheless contain many of the core characteristics of a TOD as specified in the text by Calthorpe. Therefore, both case studies are very appropriate subjects for this analysis.

An on-site analysis of South Lane Union was conducted in mid-April, after all of the interviews for this study had been conducted. The on-site analysis consisted of taking photographs of the project's unique design strategies, bicycle infrastructure, and pedestrian activity; walking the neighborhood while paying attention to housing types and residential, commercial, and public land use; and riding the streetcar.

DATA COLLECTION

The opinions of planning, architecture, and landscape architecture academics, and practitioners involved with transit-oriented development and the Pearl District or South Lake Union, and policy makers in both Portland and Seattle were integral in answering the primary research questions. Over 65 professionals were contacted to interview for this report—about 26 planning, architecture, and landscape architect academics and practitioners; about 30 planning, architecture, real estate, and public infrastructure practitioners involved with the Pearl District or South Lake Union neighborhoods; and about 12 people involved with policy making in either Seattle or Portland. A total of 21 interviews were conducted for this study, taking place over the course of three weeks.

Interviews typically ranged from 10 minutes to an hour. All interviews took place over the telephone and, to ensure high quality data collection, all interviews were recorded. Interviewees were determined based on their experience with urban planning, environmental sustainability initiatives, TOD, the design and development of the Pearl

District or South Lake Union, and policy making in Portland or Seattle. Interviewees were first contacted by email. Upon confirmation that they were interested in participating, a consent form, approved by the Institutional Review Board at the University of Texas at Austin, was provided by email to each participant prior to the interview. This consent form informed interviewees that interviews would be recorded, confidentiality was available upon request, participants could refuse to answer any questions, and the interview could be terminated at any time. No participant requested confidentiality, and therefore all names used in this report are real. After each interview, the conversation was transcribed and placed into an Excel spreadsheet so that the interviewee responses could be compared to one another.

Different questions were asked for the three different groups of interviewees—(1) planning, architecture, and landscape architecture academics and professionals; (2) practitioners involved with the Pearl District or South Lake Union; and (3) policy makers in Portland and Seattle. The interview questions were determined based on their relevancy to the primary research questions and the content in each of the literature reviews conducted—the general literature review for planning, environmental policy, ecosystem services and TOD, and the literature review for each case study. The interview questions asked to each participant in each distinct interview group are listed in the Table 3 on the following two pages.

Interview Questions

Planning and Landscape Architect Academics and Practitioners:

- What experience do you have with developing or researching with TODs? If none, what experience do you have with sustainable planning initiatives?
- How do you define "ecosystem services"?
- In your work, what level of significance do you assign to ecosystem services? Why?
- Which ecosystem services do you integrate into your practice or research? Why?
- Generally speaking, which ecosystem services do you think are most critical? Why?
- What level of significance or importance do you assign to ecosystem services in the designing and planning of future urban environments? Why?
- What ecosystem services do TODs integrate into design?
- Generally speaking, which ecosystem services do you think are most critical? Why?
- What level of significance or importance do you assign to ecosystem services in the designing and planning of future urban environments? Why?
- What ecosystem services do TODs integrate into design?
- What types of policies (regulatory, incentive-based) do you think would be most effective in moving planning to be based more on ecosystem services?

Practitioners Involved with the Pearl District or South Lake Union:

- Please describe your relationship to the TOD (South Lake Union or the Pearl District).
- What experience do you have with researching or developing TODs in general?
- How do you define "ecosystem services"?
- Please describe the environmental quality of the city (Portland or Seattle).
- How was the TOD project intended to impact the city's overall environmental quality? How has it?
- What was the initial goal of the TOD or project within the TOD?
- How did this goal incorporate ecosystem services?
- How was this goal determined?
- What were some of the key debates in planning?
- Was there anything people reached consensus on?
- Which ecosystem services does the project address? Why?
- How are these ecosystem services integrated into project design?
- How significantly does the project design affect the quality and quantity of the ecosystem services it intends to address? Does the region benefit from this affect?
- What were the limiting factors or constraints that influenced the project's ability to increase the quality or quantity of the targeted ecosystem services? Are these common in the city?
- Are TODs or related projects that incorporate ecosystem services into design more costly than projects that don't?
- From your professional perspective, what are the short-term and long-term project costs and benefits?
- How did you justify your budget?

Policy Makers in Portland or Seattle:

- How do your constituents value integrating ecosystem services into planning and development in urban environments? Into TODs?
- What are some of the key debates among your constituents related to ecosystem services and their integration?
- In what ways do you think current policies can facilitate integrating ecosystem services into TODs?
- In what ways are current policies hindering this integration?
- What suggestions do you have for policies that would support integrating ecosystem services into TODs? Into planning in general?
- Please describe your association with planning for sustainability.
- What experience do you have with researching and developing TODs?
- Are TODs a popular planning idea in your city?
- How do you define "ecosystem services?"
- What is the political justification for urban environmental policies that facilitate the integration of ecosystem services with TODs?
- What are the barriers to this political justification?
- Generally speaking, how do your constituents perceive and value environmental policy and the regulation of ecosystem services?
- What are some of the greatest barriers to developing and implementing policies that regulate or incentivize the integration of ecosystem services into TOD planning and developments?

Table 3: Interview questions used for this study.

Interview Questions Continued

Planning and Landscape Architect Academics and Practitioners:	Practitioners Involved with the Pearl District or South Lake Union:	Policy Makers in Portland or Seattle:
• Is transit-oriented development an area in planning where ecosystem services could be integrated in an effective way to enhance the quality and quantity of the urban environment? • What types of current policies do you identify that facilitate the integration of ecosystem services with transit-oriented development? • In your opinion, what are the political barriers to creating more environmentally sustainable development? • Do you think a language barrier currently exists between policy makers, planners, scientist, and citizens, for creating environmental policy? • Will there need to be an independent governing body for the successful regulation of ecosystem services? • Is the term "ecosystem services" effective? Is it more effective than sustainability?	• How was this particular project financed? • In your opinion, what are the political barriers to creating more environmentally sustainable development? • Based on your first hand experience, how does the public perceive the project? • What aspects of the project are most valued by the community of users? • Are there any efforts to monitor use or energy consumption? • In terms of progressive design and planning strategies for TODs, how does this project compare to other projects and nationally? • Does the progressive nature of the project influence how people use it? • In what areas do you believe this project is most successful? • Should it be used as a national or internationally model of TOD excellence? Why or why not? • How has the use of walking, biking, public transit, and the personal automobile changed over time in the area? • Can you make an estimate as to the percentage of residential, office, retail, and public spaces that make up the TOD? • Is ecosystem services a term you commonly hear in your practice?	• In your opinion, where would there be strong support or resistance within your constituency groups in establishing more stringent environmental policy that regulates ecosystem services? • Is "ecosystem services" an effective term for policy making? • Which ecosystem services does the case study TOD (Pearl District or South Lake Union) incorporate? • Is the TOD effective in increasing the quality and quantity of these ecosystem services? • What have been the debates in the planning of this TOD?

Table 3, cont.

LIMITATIONS ON RESEARCH

The limitations on this research include both restrictions in content and restrictions on how much and what type of data was collected. Limitations on data collection restricted the degree of analysis present in this study. At the outset, the content of this study had to be refined to ensure that completion was feasible within two semesters. Therefore, while it was recognized that there are many components of sustainable development, it is beyond the scope of this research to explore them all, particularly those tangential to environmental sustainability.

This paper focuses primarily on urban environmental sustainability, particularly the relationship between Urban TODs, planning, and ecosystem services. This thesis primarily assesses those ecosystem services directly impacted by TOD design and development, rather than the relationship between all ecosystem services (direct and indirect) and TODs. This study explores these relationships from a *qualitative* perspective. It is beyond the scope of this research to perform a quantitative analysis identifying the various benefits (monetary or other) of ecosystem services.

TOD differs from country to country. The model of transit-oriented development discussed in this paper is based on the Peter Calthorpe's model, seen primarily in the U.S., Canada, and Australia. The scale of TOD planning can range from planning decisions made for individual sites, to those of the city, region, and even megaregion. This paper briefly explores the effects of a TOD on citywide and regional environmental quality. The primary design analysis focuses on the neighborhood scale and specifically the individual projects and design elements within the quarter to half mile radius of transit stops and centers, essential to the functionality of a TOD as articulated in Calthorpe's design guidelines. Both TODs analyzed in this thesis are at the neighborhood scale.

With respect to data collection, the number of interviews conducted for this study was fewer than ideal. The response rate from persons contacted to interview was low across all interview groups, especially among policy makers. While the information obtained from the interviews conducted has provided enough information for a robust analysis, conducting 10 or even 20 more interviews, especially additional interviews with policy makers, would have been very beneficial. Had more time been available, it is likely that this goal of additional interviews would have been fulfilled. Additionally, due to limitations on time and funding, it was not possible to travel to the Pearl District. While the information obtained from neighborhood plans, zoning regulations, newspaper articles, and interviews was sufficient for purposes of this analysis, a site visit would have been helpful in obtaining additional information that is not available online as well as more photographs of specific environmental design strategies in the Pearl District.

Chapter 3: Design, The North American Model of Transit-Oriented Development

HISTORY OF THE NORTH AMERICAN TOD

The term "transit-oriented development" (TOD) was first introduced by Peter Calthorpe in his 1993 book, *The Next American Metropolis*. Calthorpe argued that the time had come to rethink suburban sprawl—the unsustainable, dominant pattern of North American development. Suburban sprawl, Calthorpe asserted, continues to serve the desires of the outdated, post World War II American Dream: of owning or residing in a large home, far outside the hustle and bustle of the city and workplace, on a large tract of land (Calthorpe 1993). He claimed that the nuclear family—consisting of a mother, father, and two children—the ideals of whom this American Dream represents, was no longer representative of the typical American family (Calthorpe 1993). Since the mid-20th century, Calthorpe described, American family composition has become more diverse. Single-parent families are more common and more and more families are having only one child, rather than two (Calthorpe 1993). The suburban home, which at one time could be sustained with only one family income, has become unaffordable for many people (Calthorpe 1993). According to Calthorpe, across the nation, the mean family income is decreasing, and commuting distances from the workplace and necessary services (grocery stores, schools, healthcare facilities) to suburban housing are increasing (Calthorpe 1993). Skyrocketing gas prices and the growing development costs of placing infrastructure extensions to greenfield subdivisions are increasing the costs of living in suburban developments, making them an unaffordable alternative to city dwelling for the average family (Calthorpe 1993). Sprawl also reflects a mentality that places no limits on natural resources, energy, or land (Calthorpe 1993). Sprawl increases air pollution, destruction and fragmentation of habitat, destruction of agriculturally and ecologically productive land, and reliance on infrastructure that perpetuates these environmental harms (Calthorpe 1993).

The alternative model of development, TOD, presented by Calthorpe in *The Next American Metropolis* represents the "new direction for growth in the American Metropolis" (Calthorpe 1983, pg. 15). Essentially, a TOD is:

> …a mixed-use community within an average 2,000-foot walking distance of a transit stop and core commercial area. TODs mix residential, retail, office, open space, and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot, or car (Calthorpe, 1993, pg. 56)

North American TODs are often nodal developments or neighborhoods, where a diverse mix of land uses that accommodate a diverse population, are located on or close (1/2 to ¼ mile or about 0.8 to 0.4 kilometers) to a regional transit system (bus, light rail, commuter rail) and good pedestrian and bicycle infrastructure. Through use of vernacular and historic architecture and buildings, and street design appropriate to the human scale, TODs emphasize the unique historic and environmental context of a place. Together, all of these design strategies work to ultimately make a place more accessible, affordable, and environmentally friendly.

While TODs vary in size and capacity, zoning makeup, and mix of land uses, with different degrees of transit, pedestrian, bicycle, automobile, and public infrastructure, the principles remain the same (excerpted directly from *The Next American Metropolis*) (Calthorpe, 1993, pg. 43):

- Organize growth on a regional level to be compact and transit-supportive.
- Place commercial, housing, jobs, parks, and civic uses within walking distance of transit stops.
- Create pedestrian-friendly street networks which directly connect local

destinations.

- Provide a mix of housing types, densities, and costs.
- Preserve sensitive habitat, riparian zones, and high quality open space.
- Make public spaces the focus of building orientation and neighborhood activity.
- Encourage infill and redevelopment along transit corridors within existing neighborhoods.

As these principles illustrate, the goal of a TOD is to concentrate high density, mixed-use development near transit and pedestrian infrastructure in attempts to reduce single occupancy VMTs, reduce unnecessary greenfield development on ecologically productive open space, and increase quality of life by creating these vibrant, human scale neighborhoods.

The theoretical idea of a TOD formally materialized in the early 1990s with Laguna West in Sacramento, California, developed by Phil Angelides and designed by Peter Calthorpe (Calthorpe 1993). The 800-acre (about 320 hectares) suburban redevelopment consisted of five neighborhoods with a diverse mix of residential housing types and costs, connected park and transit infrastructure, a retail center, extensive pedestrian and bicycling infrastructure, and various design subtleties to enhance community development and the natural environment (Calthorpe 1993). But while this development is cited as the first manifestation of the new American Metropolis, the principles which guide the design and development of a TOD are by no means new. As Calthorpe explains in his book, the TOD model he presents borrows design strategies from a number of planning theories—romantic environmentalism, the City Beautiful Movement, Camillo Sitte's urbanism, Ebenezer Howard's Garden Cities, Jane Jacob's Greenwich Village, and most notably traditional American town planning (Sitte 1889; Howard 1902; Jacobs 1961). Calthorpe also writes that the TOD is a more realistic model of planning refined from the utopian theory of the environmentally sustainable ecovillage, introduced in his first book, *Sustainable Communities*, published in 1986 (Calthorpe and Van der Ryn 1986).

The traditional American town prevailed prior to World War II and widespread adoption of the personal automobile. Unlike today's development, the infrastructure of traditional American towns did not cater to the automobile. While there was some thru traffic, frequent intersections and narrow streets ensured it would be slow and passive (Calthorpe 1993). Streets were designed to facilitate pedestrians. They were tree-lined, with sidewalks, and good connectivity to important town destinations like Main Street, parks, or schools. According to Calthorpe, in the traditional town, which predated garage doors and driveways, streets were active places lined with gathering spaces—entries to homes, porches, and balconies. Traditional towns also accommodated a variety of uses—residential, commercial, and civic—and while these were arguably segregated from one another, they were closely connected and easily and efficiently walkable (Calthorpe 1993). In the center of a traditional town was Main Street, which fluidly connected the town's vital uses together—commercial, recreation, and civic. Calthorpe's TOD is a nuanced version of the traditional American town, designed to accommodate the larger traffic flows, institutions, population, and more advanced transit systems and technologies, which the traditional town is not able to accommodate.

The TOD, Calthorpe states, is not a new type of development. Rather, he writes in *The Next American Metropolis*, it is (Calthorpe 1993, 43):

> …simply a return to the timeless goals of urbanism, in its best sense. They are principles which over time have created our most treasured man-made environments and which, although constantly evolving with culture and technology, remain true to the human dimension...

While not new, the principles which guide the design, however, "are fundamentally different from the ideas that have guided planning for the last two generations" (Calthorpe 1993, 43).

TOD DESIGN GUIDELINES AND ECOSYSTEM SERVICES

It is not explicitly stated in *The Next American Metropolis* that TODs can enhance and maintain ecosystem services in the urban environment. In fact, the term "ecosystem services" is not used at all in the book. Although Calthrope does not use the term ecosystem services to describe the environmental benefits of TODs (the term was first introduced in 1997, four years after his publication), he does identify the following primary environmental benefits associated with this nuanced type of development:

- Aid in the preservation of open space
- Add green space to the urban environment
- Help to improve air quality

These environmental benefits are similar to the four ecosystem services that TODs primarily affect recognized in this study. There are two primary differences, however, between the ecosystem services most impacted by TODs identified in this thesis and those articulated in *The Next American Metropolis*. First, while Calthorpe does encourage innovative designs that aid in wastewater drainage and treatment, he does not identify enhancing stormwater quality as an inherent benefit of a TOD, as it is recognized in this paper. Second, *The Next American Metropolis* was published in 1993, prior to widespread discussion about climate change, and prior to both Daily and Costanza's 1997 publications. Therefore, unlike this thesis, Calthorpe does not identify local and global climate regulation as a primary benefit of a TOD. It is possible that had climate change been a focal point at the time that *The Next American Metropolis* was published, the regulation of global climate would have been articulated as an inherent benefit of the reduced VMTs that TODs aim to achieve.

This section examines the specific TOD Guiding Principles, or design strategies, advocated by Calthorpe in *The Next American Metropolis*, that integrate the four most impacted ecosystem services

1. Climate regulation (local and global).
2. Fuel.
3. Processing and detoxification (urban hydrology, urban air quality, and carbon cycles).
4. Open Space (Urban and Rural), Habitat Preservation, and Recreational Services.

This section specifically examines the design guidelines for “Urban Infill/Redevelopable TODs.” This kind of TOD fuses together a couple of ideas. First, Calthorpe identifies two types of TODs—Urban and Neighborhood. Neighborhood TODs which are mixed-use, medium-density, and are located on only a local or feeder bus line, requiring about a 10 minute ride to a transit stop to connect to a major transit line (Calthorpe 1993). Alternatively, Urban TODs are mixed-use, high density, located directly on a major, well connected transit line—light rail, heavy rail, or express bus. Urban TODs usually sit about a half to one mile apart along a transit line and ideally contain a transit stop at or near their center (this design guideline is flexible for a redevelopable or infill site). They are intended to support high intensity commercial and job-creating land uses, particularly along the transit line, which has the effect of generating more transit trips. Residential densities in Urban TODs depend on how easily accessible the TOD is by transit. While the baseline goal is to accommodate moderate to high residential densities, it is recommended that Urban TODs which are highly accessible by transit should be designed with greater residential densities. Infill or redevelopable TODs refer to the location of the TOD site. Calthorpe identifies three site possibilities: redevelopable, infill, and new growth area. Redevelopable sites are areas of existing development, surrounded by urban development, that have existing low intensity uses. Infill sites are vacant parcels within the urban fabric. New growth areas are large tracts of undeveloped land that typically exist further outside of the city (Calthorpe 1993). "Urban Redevelopable/Infill TODs" are the focus of this section because the primary research questions of this study place emphasis on ecosystem services in the urban environment. Both of the case studies, in the following chapters, are examples of Urban TODs implemented in redevelopable sites with a large amount of infill development.

To illustrate how the TOD Guiding Principles integrate ecosystem services, the four ecosystem services have been divided into more specific functions, and grouped together with other services which benefit from similar design strategies. The Guiding Principles listed in *The Next American Metropolis* will be listed here, titled how they appear in Calthorpe's text. A brief description of each design guideline, summarized from his original text, will appear below the title, and will include an explanation of how these design guidelines integrate the specified ecosystem services. The design guidelines, though organized into different sections, are listed here under each section in the order they are presented in Calthorpe's book. The purpose of this section is to demonstrate that the TOD guidelines do, in fact, incorporate the hypothesized ecosystem services into design and development.

The Urban Redevelopable/Infill TOD and Climate Regulation, Reduction of Fuel Consumption, and Air Quality Improvement

The primary effect of the following TOD design guidelines is the reduction of VMTs, thereby reducing (1) carbon emissions that contribute to local and global climate regulation, (2) vehicle emissions, which aids in increasing air quality, and (3) the overall amount of fuel required for single occupancy vehicle transportation. A secondary effect of these design guidelines is the reduction of on-the-road pollutants from automobiles, which significantly benefits one of the ecosystem services analyzed in the next section—the processing and detoxification of the urban hydrologic cycle.

- **Relationship to Transit and Circulation:** Encouraging transit accessibility reduces single occupancy vehicles use and VMTs. A TOD site should be located on a major existing or planned transit line—light rail, heavy rail, or express bus service—with at least 15-minute headways. The TOD transit option (rail, bus) should also have a dedicated right of way to ensure barrier-free transit travel and should demonstrate a long-standing commitment to transit system, attractive to developers and investors. A well connected street network which enables easy internal auto access and convenient auto access to arterials and highways must accompany a TOD.

- **Mix of Uses:** TODs must be mixed-use and should meet the following preferred minimum requirements of land uses to ensure pedestrian activity and encourage mixed-use development investment. Between five percent and 15 percent of land area within a TOD must be public (parks, plazas, open space, public facilities), 30 percent to 60 percent of land area must accommodate commercial and employment uses surrounding the core of the TOD, the transit station, and 20 percent to 60 percent of land area must be residential. The ideal combinations of these minimum requirements of land uses will vary based on unique site conditions such as neighborhood character, local market demand, topography, transit accessibility, and existing and future infrastructure capacities. Horizontal mixed-use buildings are required to meet these minimums, and vertical mixed-use buildings are encouraged. Mix of uses close to one another aid in encouraging walking, bicycling, and transit use for commuting to work or to obtain daily services, therefore reducing VMTs. Requiring a percentage of public space, which may materialize as greenspace, has significant impacts on the ecosystem services addressed in the next section of this analysis—increases in carbon sequestration and aiding in the regulation of local and global climate; increases in permeable surfaces which benefit stormwater runoff management and quality; providing more recreational opportunities in the urban environment; and providing areas of potential habitat for urban species.

- **Residential Mix:** TODs should have a diverse mix of single and multi-family housing types (small-lot single-family, townhouses, duplexes, apartments, and condominiums), with different building types, affordable to a wide range of incomes. While residential housing densities will vary throughout the TOD, average minimum densities should range between 10 to 25 units per acre (about 0.4 hectares). Encouraging dense residential land uses to be located near mixed-use and transit encourages people to walk and commute to work and desired services, rather than using a single-occupancy vehicle, and thus reducing VMTs.

- **General Design Criteria:** Buildings in a TOD should be multi-storied with entries, balconies, and porches oriented toward the street to aid in the creation of a pedestrian friendly environment, a lively commercial center, and a transit-supporting community. Building architectural features should contribute to the creation of a pleasant streetscape. Parking should be located at the back of a building, and, where possible, structured parking lots should be constructed. A friendly street environment encourages pedestrian activity and walking—to destinations and transit stations to reach further destinations. Walking and use of transit significantly decrease VMTs.

- **Site Boundary Definition:** While the size of a TOD will vary, depending on parcel sizes, natural site features and existing infrastructure, redevelopable TODs should be at least 10 acres (about four hectares). The majority of parcels within the TOD should be within a quarter to half mile (0.8 to 0.4 kilometers) of the transit stop, about a 10-minute walk at most. Local streets and paths should provide easy access from these parcels directly to the transit stop. The outer boundary of a TOD should be no further than a mile (about 1.6 kilometers) from the transit stop. This strict site boundary definition ensures that TODs are large enough to accommodate the mix of uses needed to support transit systems, and that they remain small enough to feel safe and easily walkable to a pedestrian. This site boundary encourages use of transit and walking, thus reducing VMTs.

- **Coordinated Planning and Specific Area Plan:** Coordinated "Specific Area Plans," which can enforce design strategy across various property lines, should be created to ensure that the development process of the TOD, and future maintenance projects, are related and carried out in an efficient way.

Specific Area Plans can be written with regulations unique to the TOD which can create design strategies and initiatives to strengthen efforts that will increase walking, bicycling, and transit use, reducing VMTs. Specific Area Plans also can create alliances among various property owners, enabling coordinated energy saving efforts between TOD parcels.

- **Distribution of TODs**: TODs should be located along transit lines in a way that ensures vitality of their commercial core. Transit stops with competing commercial uses should be spaced at least one mile (about 1.6 kilometers) apart. If TODs are efficiently spaced, and provide a wide array of non-competing services to residents within a short walking distance of their home or office, then not only are individual TOD centers unthreatened by the services provided at other transit stops, but walking, cycling, and transit use is encouraged, and VMTs are reduced.

- **Energy Conservation:** Energy efficient buildings which utilize design strategies that efficiently capture the region's natural stocks and flows—passive solar, natural ventilation, natural shading, and natural daylighting—are encouraged. Use of natural landscaping elements for these buildings will add enhancement to the pedestrian environment. Though buildings designed on the principles of green building do not necessarily reduce VMTs, they can aid in encouraging walking by enhancing the pedestrian environment, and they do, in theory, reduce energy and fuel consumption.

- **Core Commercial Areas Size and Location, and Configuration:** The core commercial area should occupy at least 10 percent of the TOD. It should be composed of a combination of retail, office, and commercial space, all located on the ground floor, with at least 10,000 square feet (about 929 square meters) of retail, entertainment, or office space located directly next to the transit stop. The commercial core will look different depending on the TOD, but some possibilities include:
  - 10,000 to 25,000 square feet (about 929 to 2,323 square meters) local convenience shopping retail.
  - 80,000 to 140,000 square feet (about 7,432 to 13,006 square meters) neighborhood shopping centers with grocery store, pharmacy, and other needed area retail uses.
  - 60,000 to 120,000 square feet (about 5,574 to 11,148 square meters) larger, specialty retail shopping centers.
  - 120,000 square feet (about 11,148 square meters) and greater, department stores.

  Other commercial uses which generate employment are also encouraged to locate in the commercial center. Commercial and retail options located near transit, that provide necessary services when people would otherwise need to use an automobile to access, are key to reducing VMTs and creating a more pedestrian-friendly street.

- **Office and Retail Intensities:** The transit stop should be surrounded by high intensity office and retail uses. The minimum Floor Area Ratio (FAR), the percentage of land a building footprint must occupy, for office must be 0.35

and .30 for retail. Multi-storied buildings and parking structures are encouraged. For buildings with smaller capacity, a larger minimum FAR decreases the free space available for surface parking lots, thus ensuring that more site area will be developed. This effect avoids creating large holes in the urban fabric, adding to neighborhood vitality and a safer pedestrian environment. Larger FARs encourage increased building intensity and density in the commercial core, contributing to increases in transit ridership and thus reducing VMTs.

- **Upper-Story Uses:** FAR limitations may be exceeded when additional stories of office and/or residential uses are added to retail buildings in a TOD's commercial core. While use of this density bonus enables the developer to trade office and residential parking for retail parking, the intensity of retail uses must not be decreased to accommodate these additional uses. Increased densities in the commercial core of all land uses provides necessary support for transit ridership and retail, thus adding to a vibrant pedestrian environment and reducing VMTs.

- **Residential Densities:** In Urban TODs the minimum allowable residential density must be 12 units per acre (about five hectares), with an average minimum density of 15 units per acre (about six hectares). This minimum average residential density requirement is dependent upon local market conditions. Local plans may dictate maximum allowable residential densities. Residential densities may be met with a combination of a variety of housing types—single-family homes with in-law units, townhouses, or apartment buildings. These residential density requirements are required to ensure transit ridership, and thus reduce VMTs.

- **Types and Proximity of Secondary Areas:** Secondary areas are the lower intensity areas located outside of a TOD's commercial core. Secondary areas can be separated from the commercial core by a barrier, such as an arterial road, or just by distance. Land uses for secondary areas should be dependent on accessibility to the commercial core and transit stop. Secondary areas located close to the transit stop, but separated by a barrier, should accommodate large-scale employment facilities. Those located further away should be predominantly low-density residential. Secondary areas directly next to the commercial core should be composed of low-density residential, parks, and schools. In the latter case, parks should be located throughout the neighborhood, and both parks and schools should be easily accessible by foot. The presence of a secondary area encourages pedestrian traffic, and provides additional support for transit, retail, offices, and other services located in the commercial core, thereby reducing VMTs.

- **Residential Quantities and Densities in Secondary Areas, and Non-Residential Uses in Secondary Areas**: The type of residential housing available in a TOD secondary area should be appropriate to local market demand and demographics. The minimum average residential density in these areas must be six units per acre (about 0.4 hectares). Encouraging homeowners to construct ancillary, or in-law units, on their property is an effective way to meet this density requirement. Non-residential uses in secondary areas—such as offices, convenience stores, or industrial uses—should generate the same minimum density required for residential uses. While low-intensity commercial uses are encouraged throughout secondary areas, the uses provided should not compete with the commercial core. A secondary area with significant residential capacity, which provides attractive amenities to residents, helps ensure the necessary support to transit systems, services within the retail core, and the pedestrian environment, thus reducing VMTs.

- **Streets and Bikeways in Secondary Areas:** Residents in secondary areas who utilize the transit system are most likely to use a bicycle to get to the transit stop. Therefore, these areas should be connected to the TOD commercial core and transit stop with adequate bicycle infrastructure. Neighborhood streets should be designed to accommodate cyclists, and dedicated bike lanes should exist on busier, connector streets. Bicycle infrastructure in secondary areas should facilitate cycling as a safe and efficient form of transit, and should be well connected to the bicycle infrastructure within the TOD. Good bicycle infrastructure encourages cycling, thus providing secondary residents with a dependable, alternative mode of transit to the automobile, yet still faster than walking, to reach transit. Better bicycle infrastructure, therefore, can be highly effective in reducing VMTs.

- **Sidewalks**: All streets within a TOD must have sidewalks, allowing for a continuous pedestrian network. Sidewalks must be at least five feet (about 1.5

meters) wide, to accommodate two people. Where outdoor seating is present, or in the commercial core, where greater pedestrian activity exists, sidewalks can range up to 10 feet (about three meters) wide. A continuous sidewalk network facilitates a better pedestrian experience, reducing internal vehicle trips, and therefore reducing VMTs.

- **Retrofit of Existing Streets for Pedestrian and Auto Connections**: In redevelopable TODs, existing infrastructure should be retrofitted to accommodate pedestrians and cyclists. Additionally, internal and external street connectivity should be improved. When necessary, block sizes should be reduced through the creation of new streets, well connected to office and retail destinations, and pedestrian-friendly. Better pedestrian and cyclist infrastructure decreases internal auto trips, and thus decreases VMTs.

- **Pedestrian Routes**: Pedestrian routes in TODs must be direct and continuous. Pedestrian paths should always be bordered by residential and/or commercial uses, parks, or plazas. If direct pedestrian access is not possible, shortcut paths between connecting residential and commercial land uses should be provided. These paths should not utilize parking lots or the rear of buildings. An extensive pedestrian infrastructure can help encourage walking, and help eliminate the 75 percent of a household's auto trips that are not related to work commute, thus reducing VMTs.

- **Arterial Crossings and Pedestrian Bridges**: All arterial intersections in a TOD must have signal operated crosswalks. Pedestrian and cyclist-only bridges are not encouraged, as they are costly and are often underutilized. In areas previously developed, where pedestrian and cycling connections are not possible, pedestrian and bicycle bridges are an adequate solution. As previously stated, better pedestrian and cycling infrastructure reduces VMTs.

- **Bikeways and Bike Parking**: There should be a well connected network of dedicated bike lanes and bicycle-only routes throughout a TOD. This network should easily connect cyclists with the transit stop, retail, schools, and recreational facilities. It is recommended that separated bike paths be installed along greenways, and arterial streets. Dedicated bike lanes should be present on main connector streets to the commercial core, and throughout the neighborhood streets in the Secondary Areas. Bicycle parking and lockers must also be provided throughout the TOD. Bike racks should be present outside all retail, schools, and parks, both in the commercial core and in Secondary Areas. Facilities with more secure bike parking must be present at all major transit stops and offices. Bike lanes, paths, and bicycle parking should be well marked. Better bike infrastructure and protection against bike theft encourages cycling, thus reducing VMTs.

- **Transit Line and Stop Location**: The transit lines associated with the TOD transit stop should be located along a corridor of transit-supportive development. Transit-supportive development includes areas that are prime locations for employment campuses, universities, or regional destinations such as airports or centers for the arts. The transit stop within a TOD should be centrally located directly next to the commercial core to accommodate the greatest number of commuters and shoppers. In light rail TODs, the rail line should pass through the center of the TOD, or an arterial street where some retail is located near the stop. Good transit line and stop locations are key to generating the ridership necessary to support the transit system, and reduce VMTs.

- **Parking Standards**: Minimum and maximum parking standards should be established for TODs to ensure minimal spillover effects and encourage transit use, respectively. Overall, parking standards for urban TODs generally should be reduced. The following mandatory parking requirements are recommended: two to four spaces per every 1,000 square feet (about 93 square meters) of office space, three to five spaces per every 1,000 square feet of retail space, and one to three spaces per every 1,000 square feet of light industrial space. Less regulated parking requirements and no required parking maximums, enable developers to require the amount of parking they feel is most cost effective and appropriate—most likely less parking in the urban core. Less available parking discourages driving, encourages alternative modes of transit—walking, bicycling, transit—thus reducing VMTs.

The Urban Redevelopable/Infill TOD and Hydrology and Carbon Processing, and Detoxification, Increased Urban and Rural Open Space, Urban Recreational Services, and the Preservation of Habitat

The following TOD design guidelines from Calthorpe have the primary effect of increasing greenspace and permeable surfaces, and thus significantly aid in the processing and detoxification of urban water, increasing urban and rural open space and recreational services, and the preservation of habitat (Calthorpe 1993). A secondary effect of these design guidelines is increasing carbon sequestration, which benefits one of the ecosystem services analyzed in the previous section—local and global climate regulation.

- **Open Space Resource Protection**: Significant environmental features—creeks, slopes, habitat—should be integrated into TOD design as open space or conservation space. Bicycle paths should be adjacent to these sensitive places. As much open space as possible should be integrated into the TOD. Open space should be easily linked through pedestrian and bicycle infrastructure to other land uses throughout the TOD. Increased open space and conservation space adds a significant amount of permeable surfaces to a TOD.

- **Urban Growth Boundaries**: The city or town in which the TOD exists should establish an Urban Growth Boundary (UGB). UGBs are encouraged to preserve the major natural and agricultural resources outside of the urban entity. UGBs should be large enough to accommodate growth. They should be small enough to discourage sprawl, increase redevelopable and infill TODs, and assist in long-range planning strategies. UGBs significantly increase regional open space through the preservation of rural, ecologically productive land.

- **Wastewater Treatment and Water Reclamation**: Where possible in the TOD, it is desirable to process wastewater treatment on-site, either on a building or neighborhood scale. This reclaimed, treated water should be used to irrigate on-site plants and green space, or nearby agricultural land. While on-site waste water treatment and water reclamation does not directly increase greenspace, it does have implications for more affordable greenspace maintenance costs which could provide incentive for additional greenspace, and more efficient and effective stormwater filtration and treatment.

- **Drainage**: Use of natural systems—swales and retention ponds—are encouraged to aid in the management of stormwater and the recharging of groundwater, particularly in lower density neighborhoods. These environmental features should be educational and recreational installments in the landscape. Use of storm drains are discouraged. The use of natural drainage tools in a TOD encourages additional and creative use of greenspace, and is particularly effective in stormwater management and increasing stormwater quality.

- **Indigenous and Drought Tolerant Landscaping**: Plant species used in the landscaping of a TOD, on both private and public land, should be native to an area or adaptable to the regional climate. In areas where water is scarce, drought tolerant plants should be used. Mature trees and other plant species must be preserved. The increased use of native and adaptable plant species increases the frequency of permeable surfaces in a TOD that are effective in natural stormwater management.

- **Location of Parks and Plazas**: Parks and plazas in TODs should be centrally located, in areas where they will be most utilized. Ideally, parks and plazas should be located in residential areas, and adjacent to retail areas and streets. One of the benefits of locating parks and plazas in areas where people are is that it helps increase pedestrian activity. Intelligent park location also creates more accessible recreational opportunities. Locating parks near streets and other impermeable surfaces also has implications for urban stormwater management.

- **Size and Frequency of Parks**: Parks in TODs are highly encouraged, and should account for about five to 10 percent of the total land area. At minimum, there should be 3.5 acres (about 1.4 hectares) of park for every 1,000 TOD residents. Each household should be located no more than two blocks away from a village park (one to four acres or 0.4 to 1.6 hectares) with several recreational amenities—from basketball and tennis courts to picnic areas and gardens. Larger neighborhood parks ranging from five to 10 acres (about two to four hectares) in size, should have a variety of athletic fields, and should also be located close to schools and the outer edge of the TOD. Community parks, which are anywhere from 10 to 30 acres (about four to 12 hectares) in size, which are able to serve populations of about 15,000 people, should be located along bicycle networks or near open space. Environmental features, such as creeks, slopes, or trees, should be incorporated into the design of community parks. Both neighborhood and community parks should be outside of the TOD, to maintain high land use intensities near the transit stop and in the commercial core. Encouraging the integration of parks and open space significantly increases permeable surfaces, and recreational opportunities within the TOD. Parks also create a more pedestrian friendly environment, and are an additional non-auto destination, reducing VMTs and benefitting the ecosystem services addressed in the previous section.

- **Village Greens and Transit Plazas**: The creation of village greens and transit plazas, as places for people to gather in the urban core, is encouraged in a TOD. Village greens should be larger than transit plazas, and can range from one to three acres in size. These public areas should be centrally located, directly next to the transit stop, or shopping. Where possible, village greens and transit plazas may house other land uses within their boundaries, such as public buildings, or even daycare facilities. Village greens and transit stations should be well connected with pedestrian infrastructure to surrounding employment and residential land uses. Encouraging large village greens in particular, increases permeable surfaces, in addition to increasing the pedestrian environment.

- **Park and Plaza Design**: Parks and plazas in a TOD must be designed with native or adaptable plant species, characteristic of the local climate, which reflect each season. Encouraging plaza and park design with native plants increases permeable surfaces, habitat opportunities, and has implications for less maintenance—conserving both energy and water.

- **Street Trees**: Trees that provide canopy shade must be planted along all streets. Street trees should be placed no more than 30 feet (about nine meters) apart, in planters and tree wells between the sidewalk and curb. Planting street trees requires more permeable surfaces, and creates more urban habitat opportunities.

- **Size of Surface Parking Lots**: Surface parking lots in TODs should not exceed three acres (about 1.2 hectares). Parking lots larger than three acres should be divided into smaller parcels, by buildings or streets. Where possible, structured parking is encouraged, especially if parking which exceeds three acres is mandatory. Encouraging smaller parking lots can decrease the percentage of impervious cover within the TOD site, creating opportunities for parks or plazas with pervious cover.

- **Parking Lot Landscaping**: Trees should be planted on all TOD parking lots, with the goal that in 10 years, tree canopy will shade 70 percent of the parking lot's surface area. For overflow parking lots, permeable surfaces, like gravel, should be used. While this guideline is intended to create a more pleasant pedestrian environment, it has the greater environmental function of increasing pervious cover and habitat within the urban environment.

The design strategies listed above illustrate that there are a number of different, effective ways in which an Urban TOD may incorporate the four ecosystem services.

Additional Academic and Practitioner Perspectives on Ecosystem Services in TOD Design and Development

The ecosystem services and design strategies listed above, selected by the author from *The Next American Metropolis*, represent the theoretical integration of the four ecosystem services into Calthorpe's TOD design framework. To determine how ecosystem services are actually integrated into TOD design and development in practice, planning and landscape architecture practitioners and academics were interviewed. Most of those interviewed were familiar with the concept of ecosystem services (a couple of practitioners had not previously heard of this term) and the TOD principles, prior to the interview. When asked which ecosystem services TODs incorporate into design, out of eleven interviewees, almost all answered the ecosystem services associated with VMT reductions—local and global climate regulation and reduced air pollution. The design strategies identified by the interviewees which facilitated these reduced VMTs included offering alternative transit options, a dense mix of land uses close together in the urban core, and better pedestrian infrastructure. About four interviewees additionally identified the ecosystem services of increased habitat and open space as associated with TODs, through increased urban tree canopy, and concentrated development in the urban core as opposed to sprawl development. Only two out of eleven people interviewed recognized that TODs enhance urban water quality with greater urban development concentrated in one area, with increased trees and vegetation, and through utilizing low impact development (LID) techniques like rain gardens and bioswales.

When asked what the most vital ecosystem services were, climate regulation, clean water, clean air, and habitat preservation were among the most common responses. Some or all of these ecosystem services, according to the academics, professionals, and author of this thesis, are integrated into TOD design and development. However, there were some ecosystem services identified by the interviewees as most critical that are not incorporated into Calthorpe's theoretical TOD model. These ecosystem services included:

- Pollination services.

- Soil fertility.
- Food production and provisions.
- Fiber production.
- Erosion and sediment control.

The omission of these ecosystem services is probably due to the fact that Calthorpe's TOD design guidelines were published before the introduction of the concept of ecosystem services. However, some professionals believed that the lack of incorporation of these ecosystem services into TOD design, illustrate the environmental shortcomings of Calthorpe's model. In an interview, Dr. Steve Windhager, an ecologist and Executive Director of the Santa Barbara Botanical Garden, argued that the present TOD model emphasizes conservation of resources, and not production. According to Windhager, successful integration of ecosystem services to enhance the urban environment will require taking measures to increase production of these services, in addition to conserving these services. Green architecture, for example, both conserves resources and produces them—from electricity produced by solar panels to treated water produced from blackwater recycling (Windhager 2012). "Renewing of resources, not just conservation, that is where TODs need to move in the future" (Windhager 2012). To meet this goal of production, Windhager provided a suggestion for a change in the TOD design guidelines:

> A lot of ecosystem services will require some space. That said, we could integrate more than we are currently doing. If we could allow for 5 to 10% additional open space in TODs, we could accommodate a wide range of ecosystem services (Windhager 2012)

When asked about which ecosystem services academics and practitioners integrated into their research and practice, the majority of practitioners stated that different ecosystem services are incorporated into design, depending on location.

However, water—quantity, quality, recycling, stormwater treatment, and management—is almost always the primary ecosystem service integrated into their work. Climate regulation and air quality were the second most common answers. Other incorporated ecosystem services included: biodiversity, habitat, cultural systems, aesthetic resources, heat island effect, and food production. Since most academics and professionals neglected to recognize urban hydrology management as an ecosystem service already integrated into TOD design, the lack of perceived emphasis on urban hydrology systems was recognized by the author as an additional environmental limitation in TOD design as it is currently conceived.

Despite these environmental shortcomings, many of the interviewees, when asked, did identify TODs as a potential area in urban planning and sustainable planning initiatives, where ecosystem services could be integrated in an effective way to enhance the quality of urban environments. Julie Raish, a former member of the Ecosystem Design Group at the Lady Bird Johnson Wildflower Center, said that TODs are a unique planning tool because they provide the opportunity to accomplish multiple goals and planning agendas, simultaneously. In an interview, Raish commented regarding TODs:

> I think these are the types of developments where we need to think more innovatively about how and where we can get more ecosystem services, exactly because of where they are located. I think that urban environments are lacking and often overlooked as opportunities for these types of services (Raish 2012)

Other interviewees commented that TODs were a great alternative to sprawl, and emphasized the importance of redevelopable and infill TOD projects on successful increases in urban density and alternative transit systems. Dr. Ken Yocom, an Assistant Professor in the Department of Landscape Architecture at the University of Washington in Seattle, said, "[a] lot of [TOD success] depends on existing infrastructure and existing lines. It is really about figuring out ways to work on and build off of existing patterns, instead of creating new ones" (Yocom 2012).

THE VALUE OF ECOSYSTEM SERVICE TO ACADEMICS AND PRACTITIONERS

When asked about what personal level of significance assigned to ecosystem services in their work, each academic and practitioner interviewed who was familiar with the concept answered somewhere in the range of "very high" when project goals and budget permitted. When asked why, individuals emphasized the significance of these services to their work and lives. Dr. Mark Simmons, Director of the Ecosystem Design Group at the Lady Bird Johnson Wildflower Center, commented, "[Ecosystem services] are everything. It is what drives all of our design research and our design consulting services" (Simmons 2012). Ken Yocom observed that ecosystem services can help to provide value to individual ideas and sectors that are not traditionally attributed values. He stated, "if you can provide value to something that isn't normally accounted for, and show that value, then you are more likely to get a project or to sell an idea" (Yocom 2012). Dr. Kristina Hill, an Associate Professor of Landscape Architecture at the University of Virginia, said:

> Without ecosystem services, humans would have to replace too many basic services with our own expensive systems—assuming we had the technology to do so, and accepted the implications for quality of life in doing so (Hill 2012)

From the interviews conducted in this study, it is clear that academics and practitioners familiar with the concept of ecosystem services highly value the integration of these services into planning and design, and believe that TODs, paired with encouraging policy (see Chapter 7) are an effective planning strategy to further facilitate this integration.

CONCLUSION

As this chapter illustrates, the TOD design strategies articulated by Calthorpe in *The Next American Metropolis* do have positive primary and secondary affects on the four ecosystem services identified in the outset of this study: climate regulation (local and global), fuel, processing and detoxification (urban hydrology and urban air quality), and open space, habitat preservation, and recreational services. From interviews with academics and practitioners, however, it appears that Calthorpe's TOD model does not incorporate what are perceived to be some of the most vital ecosystem services. Despite the different perceptions of which ecosystem should be incorporated into TODs, almost all interviewees identified this planning strategy as an effective way to further integrate ecosystem services, highly valued by the academics and practitioners interviewed, into the urban environment.

The next two chapters explore how Calthorpe's TOD design strategies have been implemented in practice in two North American cities. For each case study, project background information is provided and, using information obtained from project plans, zoning codes, and interviews with practitioners related to the project, an analysis is conducted of how the design strategies utilized integrate ecosystem services. Chapter 7, following the case studies, provides an analysis of how the ecosystem services integrated into the case studies differ, and concludes with an evaluation of the perceived and political value of ecosystem services in each city.

Chapter 4: Portland, Oregon Pearl District Case Study

CONTEXT AND SITE ANALYSIS

Portland's Pearl District is considered by design and transit professionals to be a national model of environmental TOD excellence. The Pearl District is a neighborhood located in the Portland's River District, adjacent to downtown. The Pearl District spans about 100 city blocks and has a total area of 285 acres (about 115 hectares) (The Pearl District 2005). The district is bound by the Willamette River on the north, NW Broadway on the east, Burnside Street on the south, and the Interstate 405 freeway on the west (see Figure 5 for the area and boundaries of the Pearl District) (The Pearl District 2005). Main attractions located within the neighborhood include the North Park Blocks, the iconic Powell's City Books, Whole Foods, Portland's Main Post Office, the former 34-acre (about 14 hectares) Hoyt Street Rail Yards, the 13th Avenue Historic District, the redeveloped historic Blitz-Weinhard brewery blocks, and the historic Portland Armory (The Pearl District 2005).

Figure 3: The Pearl District (Bonnet 2008)

Figure 4: The Pearl District, view of Brewery Block 2 (Gerding Edlen 2012)

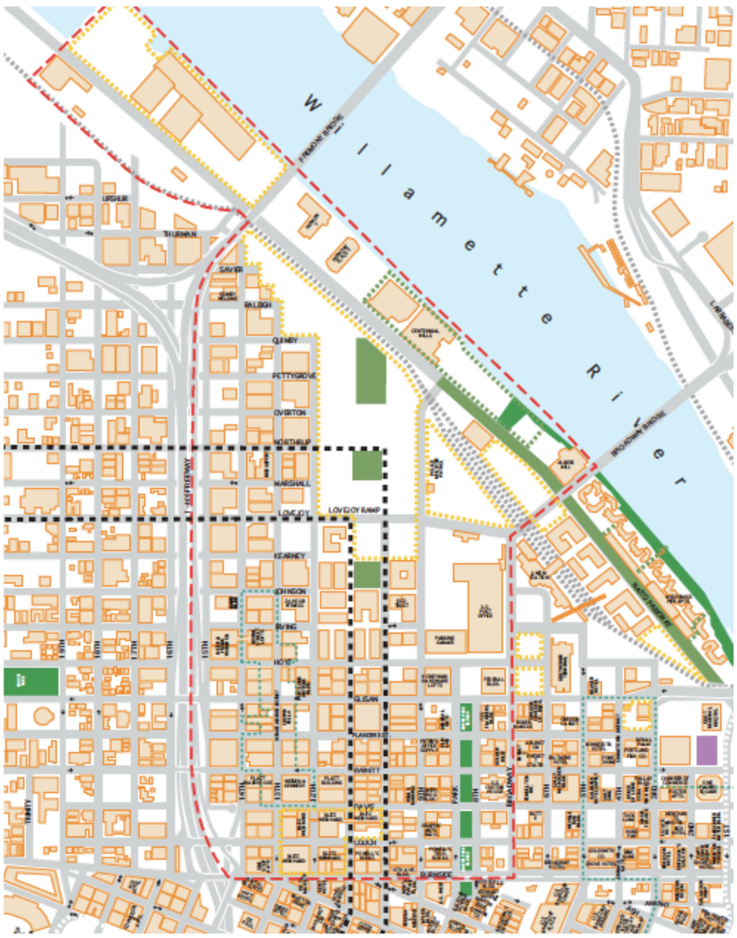

Figure 5: Pearl District boundary, outlined by the dotted red line (PDC 2001)

In the late 1980s, the Pearl District, which then consisted of underutilized warehouses, some light industry, and 34-acres (about 14 hectares) of abandoned rail yards, was targeted by the city as an area for growth (The Pearl District 2005). Redevelopment of the neighborhood began in the late 1990s. The first redevelopment projects were primarily residential. A number of historic warehouse buildings were converted into luxury lofts, and new high-rise residential buildings were constructed. As the area evolved, mixed-use, greenspace, public transportation, bicycle, and pedestrian infrastructure were further integrated into the neighborhood (Solheim 2012).

In 2001, the Portland Streetcar was introduced into the Pearl District, solidifying the neighborhood's status as a TOD (Portland's well-known MAX light rail line provides transit services just outside the Pearl District's southern border). The streetcar, which connects the Pearl District to downtown Portland and Portland State University, has attracted billions of dollars of development investment into the neighborhood (Solheim 2012). Since the addition of the streetcar, growth in the neighborhood has been tremendous. In 2000, there were about 9,000 jobs and 1,300 residents in the Pearl District. With complete buildout, it is estimated that these figures will grow to 21,000 jobs and 12,500 residents (PDC 2001).

Today, the Pearl District is one of Portland's most desired neighborhoods. The moderate density of the Pearl District, accessibility of pedestrian, bicycle, and public transit infrastructure, large number of LEED certified green buildings, and acreage dedicated to urban parks, have contributed to its livability, and notoriety as a model, environmentally friendly, TOD. These design and accessibility measures appear to be enhancing the local natural environment. In an interview, Renee Loveland, Development Manager at Gerding Edlen, a major developer in the Pearl District, commented that ridership on the Portland Streetcar is higher than anyone contemplated, and that the district is inundated with pedestrians and bicyclists. Al Solheim, a developer nicknamed the "father of the Pearl District," commented that a lot of people who live in the neighborhood do not even have cars. In the following sections of this chapter, the specific TOD design strategies of the Pearl District will be explored, through the lens of Calthorpe's TOD model, to determine which ecosystem services are integrated into the district, how these ecosystem services are integrated into TOD design in practice, and the value of these services to the practitioners—planners, architects, landscape architects, and developers—within the Portland building community. This chapter concludes with discussion of the successes and shortcomings of the neighborhood from an ecosystem services perspective.

PEARL DISTRICT HISTORY AND BACKGROUND

In the mid-1800s, the site of today's Pearl District was marshland. Soon afterwards, the northern portion was developed as one and two-story residential housing to accommodate Portland's growing blue-collar European immigrant population (The Pearl District 2005). Transportation infrastructure was introduced in 1896, with the construction of Union Station. In 1905, in response to the increase in population experienced from the Lewis and Clark's Exposition, the rail yards were expanded to accommodate the arrival of the Portland & Seattle Railway (later called the Spokane, Portland & Seattle Railway, or SP&S), a passenger rail line (The Pearl District 2005). Warehouses were built to accompany the rail yard (the rail yard was later called the Hoyt Street Yards because of their geographic location on Hoyt Street), and the area became the transportation hub of the city (PDC 2001). Manufacturing and associated uses prospered with transit, and the neighborhood thrived as a warehouse and industrial district up until the early 1950s (PDC 2001).

During the 1950s, in Portland as elsewhere, passenger and freight rail began taking a back seat to interstate freeways and air travel (PDC 2001). With decreased demand, passenger rail service stopped, and the population of the once-thriving neighborhood relocated (The Pearl District 2005). While services for freight trains and service locomotives continued until the 1970s, the area became vacant and neglected (PDC 2001). The neighborhood's declining rents and surplus of vacant warehouses attracted an artistic community of tenants who took up both legal and illegal residency (PDC 2001). With these new residents, the district became an eccentric neighborhood, filled with small businesses, art galleries, and auto shops (PDC 2001). Around this time, the district was nicknamed the Pearl District, after local gallery owner Thomas Augustine compared the galleries and artists lofts, concealed in the old industrial warehouse buildings, to pearls inside oysters (PDC 2001).

An urban design study, followed by interest from a few local developers, and a series of city and neighborhood plans written and adopted in the 1980s and 1990s, targeted the district as a prime area for mixed-use development. Outlined in these plans were specific design goals for redevelopment. The State of Oregon mandates urban growth boundaries (UGBs) for each municipality over 2,500 people to protect rural and agricultural lands. The redevelopment of an area close to downtown, with high potential buildout job and residential capacity, relieved pressures to expand Portland's existing UGB (Anderson 1999; City of Portland 2001). In an interview, Al Solheim remarked that the neighborhood's proximity to downtown Portland, city bridges, freeways, and arterials, paired with great buildings constructed around 1910 to 1925, made the area a prime location for development.

The following plans have been integral to the successful redevelopment of the district. The goals and design guidelines of these plans are analyzed in the subsequent sections of this chapter:

- *Central City Plan* (1988)
- *River District Vision Plan (*1992)
- *University District and River District Plans* (1994)
- *River District Design Guidelines* (1996)
- *Pearl District Development Plan* (2001)
- *Portland River District Park System Urban Design Framework Study* (2001)
- *North Pearl District Development Plan* (2008)
- *Portland Plan* (recommended March 2012)

New development in the Pearl District began in the 1990s, and attracted high profile restaurants, and retail shops. In 2001, the nations's first contemporary streetcar was opened, and ran directly through the Pearl District, connecting the neighborhood to downtown and Northwest Portland and Portland State University (PDC 2001). The Portland Streetcar solidifed the neighborhood's status as an urban redevelopable/infill TOD. Demand for expensive residences in the neighborhood increased, and a number of historic warehouse buildings were converted into loft residences to accommodate this demand. Additionally, landmark parcels in the area were selected for redevelopment, to accommodate the growing residential and employment populations. These landmark parcels included the Hoyt Street railyards, the Armory, and the Blitz-Wienhard Brewery Blocks (see Figure 6 on the following page for a map of the neighborhood and list of completed and in progress-developments).

Figure 6: Map illustrating River District redevelopment projects (includes the Pearl District) (PDC 2007)

A number of different financing mechanisms were used to pay for the Pearl District redevelopment. Private financing was the most common, since a number of the properties are owned by individual property owners (Solheim 2012). Public infrastructure was paid for with public money, in addition to property easements given to the City of Portland to develop additional parks (Solheim 2012). Government subsidies were provided to encourage affordable housing and green buildings. The district also was desginated as a tax-increment finance (TIF) district by the city, to help encourage development and investment in the area and to aid in the cost of the streetcar (Solheim 2012).

Today, the Pearl Districtis redevelopment significantly contributes to Portland's image as an environmentally progressive city, and is commonly cited as the model of what can be achieved with environmetnally progressive urban policy and political will. Even with higher rents than pre development, the district has some of the highest residential and employment densities in the city. As the Pearl District continues to evolve, and amenities, housing, and jobs within the area increase, pedestrian, bicycle, and streetcar ridership grow. The high consumption of alternative transit infrastructure, developer's reuse of exisitng buildings and infrastructure, and frequent parks within the neighborhood, have contributed to the Pearl District's well-known reputation as an environmentally friendly TOD.

GOALS, DESIGN, AND ECOSYSTEM SERVICES

Goals According to Plans and Practitioners

According to practitioners, as the vision of the Pearl District has evolved over time, so have the development goals. "What the Pearl District has become," Al Solheim said, "was not envisioned." Solheim commented that initially, in 1980, the vision for the

Pearl District was light industry, which then evolved into housing. He added that the initial goals of the neighborhood redevelopment were also transportation driven—a way to encourage urban living and walking, thus taking stress off the city highways. Solheim claims the reasoning was that if you increased industry and housing density in the center of the city, freeways and other transportation infrastructure (aside from the streetcar) would be less necessary. Another design practitioner, Don Stastny, Principal at StastnyBrun Architects, who has been involved as an architect with the planning and design of the district since its inception, recalled that the redevelopment of the Pearl District was really an attempt at:

> how to create a new part of the city that has a strong mix of uses, that has a very strong housing component, with the commercial, retail, and cultural aspects of the city (Stastny 2012)

The initial development goals articulated in the early plans for the Pearl District redevelopment support the statements of the practitioners. The primary goal of the 1988 *Central City Plan*, which set the stage for the planning of the Pearl District by exploring development opportunities in central Portland, was to establish the Central City as Portland's heart of commerce and community activities. It was envisioned to be a place with a mix of residences and businesses that captured the city's historic character and increased liveability for all Portland citizens (Bureau of Planning 1988). The plan specifically sought to increase housing in the city by 10,000 units and 25,000 jobs by 2010 (Bureau of Planning 1988). The 1992 River District Vision plan created a new orientation of the River District to the Willamette River, a new district boundary, and the context for new development within this redefined boundary. The boundary of the River District was defined as an area composed of multiple neighborhoods, including the Pearl District (Bureau of Planning 1994). Creating community and cohesion among these new residential populations and neighborhoods was the central goal of the plan (Bureau of Planning 1994).

As a result of the *River District Vision* plan, a steering committee was formed to draft a River District development plan to present to City Council (Bureau of Planning 1994). The 1994 *University and River District Plans* supported the development goals of the *Central City Plan*, with the further goal of making the River District an extension of downtown, with a substantial residential and employee population. The idea was to make the River District "the kind of place where people would like to live, work, and play" (Bureau of Planning 1994, 11). Another major goal of this plan was to increase transportation infrastructure at all levels; this included the development of a streetcar to service the area.

The 1994 *University and River District Plans* was significant in that it was the first plan to recognize enhancement of the natural environment as a primary goal of development. All the practitioners interviewed for this study commented that the enhancement of the natural environment was not an explicit, but rather implied goal of development. Mark Raggett, a Senior Planner in Portland's Bureau of Planning and Sustainability, said that it was understood among the parties involved:

> that if we can make this a vibrant, compelling, urban high density place, that is good for the city as a whole, and it is good for the environment and the natural resources that surround the city and are within its boundaries (Raggett 2012)

Solheim remarked that the inherent environmental benefits of a central city development with a strong transit component were understood. While integrating the natural environment into the initial planning may not have been explicit, the Pearl District has "evolved into a sensitive, eco-friendly area," with design guidelines that improve stormwater retention, require energy efficiency for new buildings, and encourage walking and bicycling (Solheim 2012).

From reviewing the plans, it appears that beginning in 1994, enhancement of the natural environment became a goal for development in the River District, and in later plans, the Pearl District. In the 1994 plan, infill development is aggressively encouraged to reduce the need for greenfield development. Enhancement of the natural urban environment is emphasized by incorporating water features into the neighborhood, increasing urban greenspace, and improving air quality through more extensive mass transit systems (Bureau of Planning 1994). The 1996 *River District Design Guidelines* support the environmental goals of the 1994 *University and River District Plans*, through strategies which include using green stormwater infrastructure, increasing street vegetation, and enhancing public greenspace natural features, and their community significance (Bureau of Planning 2008).

In the 2001 *Pearl District Development Plan*, the District's most influential plan to date, goals to enhance the natural environment become more generalized. However increasing greenspace in the Pearl District, and improving transit systems and pedestrian connectivity in the area were emphasized. Providing neighborhood amenities, attracting development, and increasing residential and job capacity within the neighborhood were the primary goals of this plan (PDC 2001). In 2001, the City of Portland also commissioned the *Portland River District Park System Urban Design Framework Study*. One of the contributing authors of this study was the well-known landscape architect Peter Walker. While this plan's goals focused on highlighting the significance of Portland's natural features and improving park and public space aesthetics, enhancing the city's ecosystem services was not an explicit goal.

Goals of enhancing ecosystem services are most prominent in the 2008 *North Pearl District Development Plan*, which focused on guiding development decisions in the area of the Pearl District north of NW Lovejoy Street. Increasing density and green building, and decreasing natural resource consumption were among the primary environmental goals outlined in this plan. Additional goals include enhancing community, building stock, and improving access to services and transit (Bureau of Planning 2008). While the 2008 *North Pearl District Development Plan* remains the most recent of the city's plans which directly target development in the Pearl District, the recommended draft of the *Portland Plan*, which will guide future city development, was recently introduced in March 2012. This draft emphasized improving social equity in Portland, in addition to creating a connected habitat, healthier watersheds, and reducing carbon emissions (City of Portland Government 2012).

Currently, Portland is in the process of drafting *Central City 2035*, an update of the 1988 *Central City Plan*, which will impact development in the Pearl District (BPS 2012). While it is projected that the final draft of the plan will not be completed until 2013, the city has released a summary of the plans goals, which are listed exactly as (BPS 2012, 3):

- Maintaining the Central City's role as a **regional center** for employment and other activities,
- Building **healthy connected urban neighborhoods** in the central City,
- Improving the **design and civic vitality** of the Central City,
- Providing for **mobility** and access,
- And Improving the Central City's **green and natural systems** [**original emphasis**]

Consistent with the observations of the professionals in interviews for this study, the initial development goals of the Pearl District did not explicitly seek to enhance the natural environment, but have evolved to incorporate ecosystem services with the development goals of the city. The following section examines how the Pearl District is consistent with Calthorpe's TOD model, and how the four ecosystem services accounted for in Calthorpe's TOD model (see Chapter 3) are integrated into the design of the Pearl District.

Ecosystem Services in TOD Design According to Plans and Practitioners

The Pearl District is a neighborhood directly serviced by a streetcar, sits adjacent to downtown Portland, and consists of a series of redeveloped existing buildings and infill development of open lots, developed for a variety of moderate to high-density uses. Therefore, it qualifies as an urban infill/redevelopable TOD. The Pearl District contains multiple transit stops and nodal TODs (Calthorpe's TOD and design strategies, discussed in Chapter 3, describe an area surrounding only *one* transit stop).

Climate Regulation, Reduction of Fuel Consumption, and Air Quality Improvement

All of the Portland practitioners and policy makers interviewed for this study believe the Pearl District has been very effective at reducing VMTs, and therefore contributes to local and global climate regulation, reduced fuel consumption, and improves air quality. To begin, the mix of uses within the Pearl District is consistent with the mix of uses Calthorpe suggests for an urban TOD successful in supporting transit and reducing VMTs—about 20 to 60 percent housing, 30 to 70 percent commercial and employment, and five to 15 percent public (Calthorpe 1993). The Pearl District consists of the following three base zones:

1. Open Space (OS) is defined as public and private open space, parks, and recreational areas. OS makes up about five percent of neighborhood zoning.
2. Central Commercial (CX) is defined as intense, pedestrian oriented, commercial development, intended to accommodate a variety of uses, “with a strong emphasis on a safe and attractive streetscape” (Bureau of Transportation 2010, 7). CX represents about eight percent of the Pearl District zoning.
3. Central Employment (EX) is defined as mixed-use, primarily for industrial and commercial uses. It allows for residential, but this should not be the dominant use. EX accounts for about 86 percent of Pearl District zoning (See Figure 7 below for zoning composition).

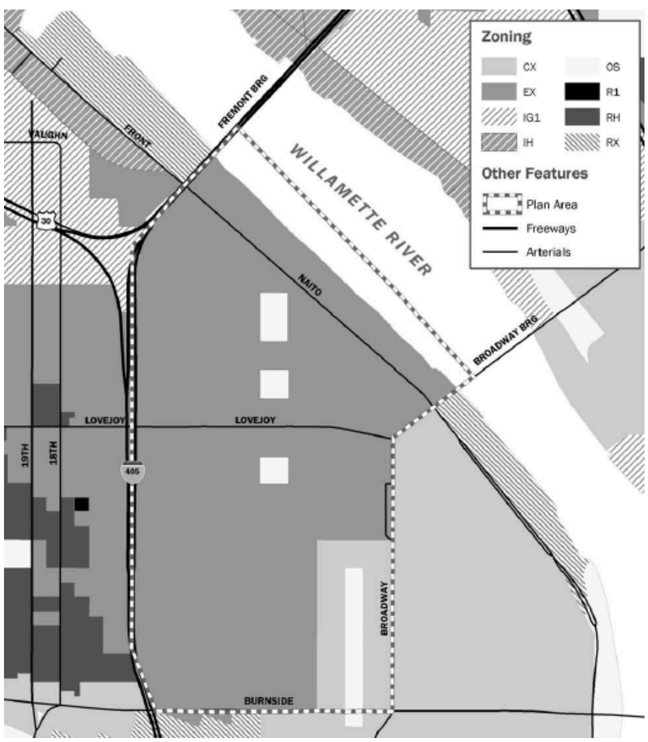

Figure 7: Pearl District zoning classifications (Bureau of Transportation 2010, 9)

Figure 8 on the following page shows predominant building use. It illustrates that the Pearl District composition is similar to Calthorpe's model, with commercial and employment the dominant land uses, followed by housing and public space. Also consistent with Calthorpe's design guidelines, there are often multiple uses per building, and the predominant building land use is usually different from the ground floor use (Bureau of Transportation 2010).

Figure 8: Predominate Pearl District building uses (Bureau of Transportation 2010, 11)

While not illustrated on the map, the available housing in the Pearl District is diverse, consisting of single and multi-family housing, with options for affordable housing (PDC 2008). At full buildout, with a residential population of 12,500, the neighborhood average residential density will be about 43 people per dwelling acre (about 0.4 hectares). Using Portland's average of 2.45 persons per household, the estimated units per acre at this population are about 5,102. With an area of 285 acres (about 115 hectares), at full buildout the Pearl District will have an average of about 18 housing units per acre. This figure is consistent with Calthorpe's suggested minimum of between 10 and 25 units to support transit systems and retail and commercial land uses to reduce VMTs (The Pearl District 2005).

There are 12 internal stops for the Portland Streetcar. The distances between each stop average from 0.1 to 0.2 miles (about 0.16 to .32 kilometers), and no stop is located more than a quarter mile (about 0.4 kilometers) to the district boundary. From within the Pearl District, the greatest distance a resident or commuter would need to walk to access a streetcar stop would be a quarter mile (about 0.4 kilometers), or 1,320 feet (about 402.3 meters) (see Figure 9 on the following page for a map of the streetcar transit route and stops in the Pearl District). This maximum is considerably lower than the 2,000 foot (about 610 meters) maximum specified in Calthorpe's model TOD (Calthorpe 1993). An additional study conducted by the City of Portland's Bureau of Transportation found that up to five tranist lines (including the streetcar) could be accessed in the Pearl District wihtin a quarter mile walk Pearl District (see Figure 10 on the following page).

Figure 9: Portland Streetcar stops in the Pearl District (Portland Streetcar 2011).

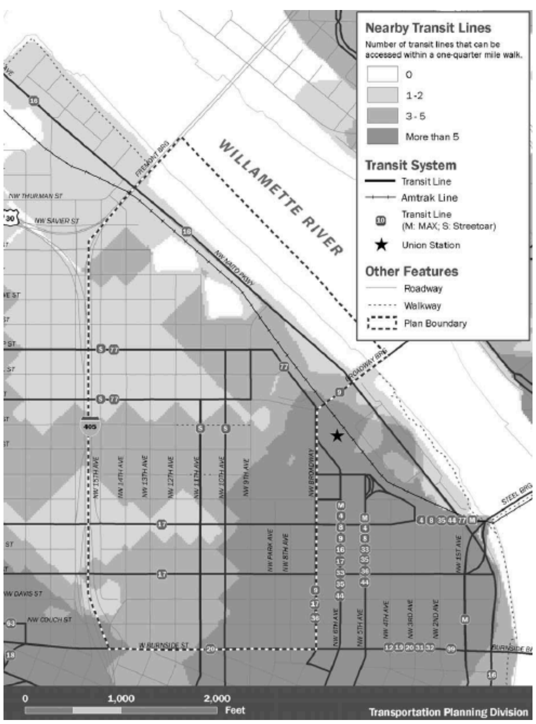

Figure 10: Pearl District transit line accessibility, within a quarter-mile walk (Bureau of Transportation 2010, 14).

The Portland Streetcar runs about every 13-minutes during workday hours, extending frequency time to about every 14 to 20 minutes in off-peak hours (Portland Streetcar 2011). During peak hours, the frequency of streetcar service exceeds the 15-minute frequency suggested by Calthorpe for an efficent TOD transit system by about two minutes (Calthorpe 1993). The MAX light rail line, which services the area just outside of the Pearl District's southern boundary, but is within walking distance for residents of the Pearl District, has service as frequent as every three minutes during peak hours (TriMet 2012). Ridership on the transit lines is significant, and has far exceeded expectations (Loveland 2012). Some streetcar stops in the Pearl District average from 751 to 1,000 riders daily (Bureau of Transportation 2010).

Consistent with Calthorpe's TOD design strategies, the Pearl District has excellent street connectivity, with extensive pedestrian and bicycle infrastructure. Getting around the Pearl District is easy in a personal automobile, as the Portland street grid is small and well connected to downtown and greater Portland. Large surface area parking lots in the Pearl District are discouraged and represent the minority of off-street parking options (for off-street parking in the Pearl District there are only 2,001 surface lot parking spaces to 8,264 parking spaces available in parking structures) (Bureau of Transportation 2010). In accord with Calthorpe's suggestions, emphasis is placed on metered, on-street parking, and leveled parking garages for off-street parking, when necessary (Bureau of Transportation 2010). Generally, office parking requirements in the Pearl District align with those suggested by Calthorpe.

The Pearl District also is an easy neighborhood for bicyclists to get around. The City of Portland has provided marked bicycle lanes throughout the Pearl District, and has constructed four bike boulevards connecting the neighborhood to west and east Portland. Historically, the City of Portland has included strict requirements for bicycle parking in the city zoning code. In 2009, the city set bicycle parking requirements of 1.25 long-term spaces per multi-family residential unit, and one space per 10,000 square feet (about 929 square meters) of office building area, requiring a minimum of two spaces (Bureau of Transportation 2010). The Pearl District has about 385 bicycle racks within its borders, and the Bureau of Transportation has been asked to add more bike racks to the neighborhood (Bureau of Transportation 2010).

In addition to being bicycle friendly, the Pearl District also is pedestrian friendly, an essential element of a TOD (Calthorpe 1993). In a recent plan, the Portland Bureau of Transportation classified the entire Pearl District as a Pedestrian District. In an area classified as Pedestrian District, "the needs of pedestrian travelers are considered on at least equally footing with those of other modes" (Bureau of Transportation 2010, 16). Based on information provided in interviews and district plans, the pedestrian experience in the Pearl District was of the utmost concern. Significant efforts have been made to ensure the district provided a safe and pleasant walking environment. Maintaining neighborhood character, creating sidewalk buffers, updating street lighting, increasing sidewalk connectivity and width, and adding more art, street trees, and furniture to sidewalks, were among policies suggested to improve the Pearl District's pedestrian environment (PDC 2001).

Incorporating energy efficient buildings into the Pearl District was another development strategy used to further reduce the district's energy consumption (Loveland 2012). The city worked with developers to facilitate the addition of LEED buildings to the neighborhood, which now contains several such buildings. As the Pearl District grows, plans for more LEED development in the neighborhood increase (Bureau of Planning 2008). While the LEED green building certification predates *The Next*

American Metropolis by more than a decade, energy conservation and efficient building design is one of Calthorpe's TOD design guidelines.

Hydrology and Carbon Processing and Detoxification, Increased Urban and Rural Open Space, Recreational Services, and Preservation of Habitat

Maximizing the availability, utility, and a connected network of open and greenspace was strongly considered in the design of the Pearl District. In 2001, the city commissioned the *Portland River District Park System Urban Design Framework* which established a design framework for the four major parks within the Pearl District, consistent with the Pearl District and Parks and Recreation Department's development goals (see Figure 11 on the following page for an aerial photograph of the Pearl District with the parks highlighted in light green). Outlined in this plan, were design strategies to incorporate local history into park program, to bring about:

> the deeper meanings of the natural cycle of water collection and storage, the visual relationship between water and land, and the natural and social life that they support (Portland Parks and Recreation et al. 2001, 2)

In North Park Square, the addition of a wetland was suggested as a design strategy to symbolize "one of America's most important natural resource issues" (Portland Parks and Recreation et al. 2001, 14). In South Park Square, a water basin feature, in which water mimics waves on the seashore, was proposed (Portland Parks and Recreation et al. 2001). Consistent with Calthorpe's design guidelines, the use of native plant species for all Pearl District parks is emphasized in this plan.

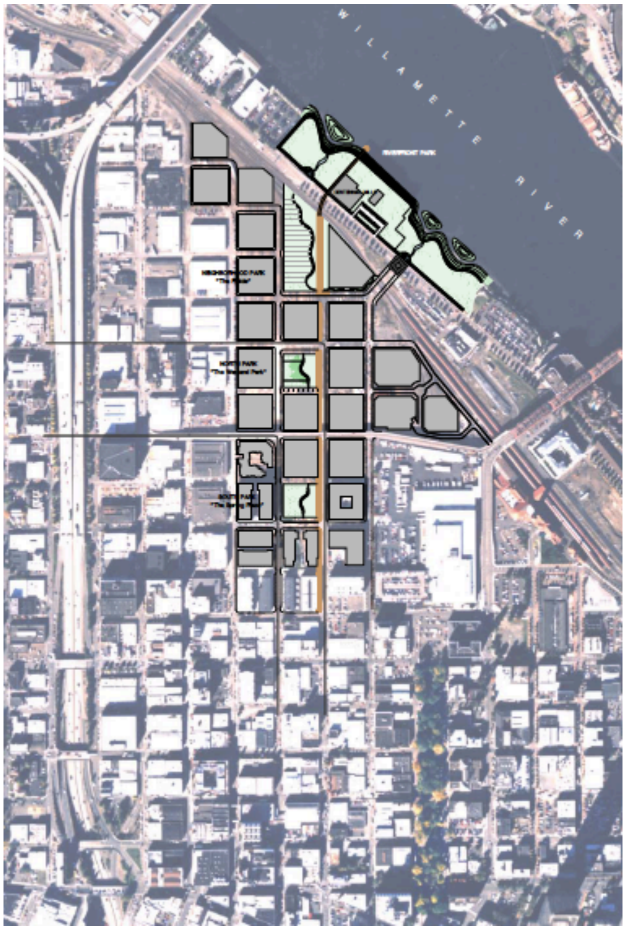

Figure 11: Existing and planned Pearl District Parks (Portland Parks and Recreation et al. 2001, 3)

Of the four parks outlined in Walker's plan, only two have been completed—Jamison Square, the southern most park, and Tanner Springs, directly north of Jamison Square. Jamison Square, at 0.94 acres (about 0.38 hectares), includes some greenspace for passive recreation, a fountain which uses energy efficient pumps, a statue, and some public art (Portland Parks & Recreation 2012). Tanner Springs Park, with an area of 0.92 acres (about 0.37 hectares), includes some greenspace and paved paths for passive recreation, some public art, and flowing runnel, and a small wetland (Portland Parks & Recreation 2012). These parks have been very popular with the Portland public, and

Jamison Square, in particular, with Portland families. This unexpected user demographic has prompted the city to explore the introduction of recreational facilities into Jamison Square (Bureau of Planning 2008).

The largest parks in the Pearl District are currently under construction—Fields Neighborhood Park, just north of Tanner Springs Park and Centennial Mills, adjacent to the Willamette River. At 3.2 acres (about 1.3 hectares), Fields Neighborhood Park will have a variety of programs, which may include "space for the visual of performing arts, for community-building activities and visual/physical access to the Willamette River" (Portland Parks & Recreation n.d.). The park also will include environmental design features to enhance its character, and will provide the Pearl District with a vital connection to the Willamette River (Portland Parks & Recreation n.d.).

Centennial Mills, at four acres (about 1.6 hectares) the Pearl District's largest park, was acquired by the Portland Development Commission in 2000. The following five redevelopment principles (directly excerpted from the *Centennial Mills Framework Plan*) have guided the design and development of the under construction park (PDC et al. 2006, 1):

- Provide Open Space
- Capture History
- Define a Community Focal Point
- Strengthen Connections
- Embrace Sustainability

When completed, it is expected that Centennial Mills will be one of the area's main attractions, and will be a catalyst to more mixed-use development along the Willamette riverfront. Of all the Pearl District Parks, Centennial Mills places the greatest emphasis on incorporating ecosystem services into design. Objectives to fulfill the goal of developing the park in an ecologically sustainable manner include (PDC et al. 2006):

- Integrating LEED buildings and best green building practices into site design.
- Reusing materials.
- Utilizing nuanced methods for on-site stormwater treatment.
- Using local products when possible.
- Enhancing fish and wildlife habitat along the Willamette riverbank.

In total, open space acreage in the Pearl District at full buildout, excluding pocket parks, which are strongly encouraged in the *Pearl District Development Plan*, measures about nine acres. Since the site is 285 acres (about 115 hectares), open space represents only about three percent of the total Pearl District area, significantly less than Calthorpe's recommendation of five to 10 percent per individual TOD site. Calthorpe also suggests neighborhood parks raging from five to 10 acres (about two to four hectares) in size and providing recreational opportunities. The largest park in the Pearl District, Centennial Mills, is only four acres. However Centennial Mills has been designed to accommodate a large field for recreation (PDC et al. 2006). At full buildout of 12,500 residents, nine acres (about 3.6 hectares) of open space provides only 0.72 acres (about 0.29 hectares) per thousand population, considerably less than Calthorpe's guideline of 3.5 acres (about 1.4 hectares) per thousand population (Calthorpe 1993). It should be noted that the development of the Pearl District, a dense residential and employment district, does reduce sprawl and thus conserve rural open space, though it is impossible to calculate how much. Portland's UGB, consistent with Calthorpe's UGB guideline, aids in this conservation.

The ecosystem service of urban hydrology has only been integrated into Pearl District design in the past few years. Goals to integrate neighborhood-scale natural stormwater management were first introduced in the most recent Pearl District Plan, the 2008 *North Pearl District Plan*. Consistent with the city's Bureau of Environmental Services "Grey to Green" initiative, the plan presents the integration of bioswales, street trees, additional vegetation, and green streets infrastructure. It also encourages on-site water and wastewater recycling in Pearl District buildings for more natural, effective, and economical stormwater management (PDC 2008). The plan even suggests creating a "stormwater walk" to educate the public about new technologies for natural, and sustainable stormwater management (PDC 2008). In addition to this plan, natural techniques for stormwater management and water conservation have been introduced at the individual project level—in the Centennial Mills project design, and in individual Gerding Edlen and LEED buildings throughout the district (PDC et al. 2006; Loveland 2012). One of the design features included on one of the Gerding Edlen Brewery Block buildings, Block 4, the M Financial building, was a vegetated ecoroof, to assist in building insulation and mitigate stormwater runoff (Loveland 2012).

Efforts for carbon sequestration (to mitigate climate change and therefore postdate *The Next American Metropolis*) are explored in the most recent draft of the *Portland Plan* but are not outlined in any of the Pearl District plans. However, the design strategies of additional greenspace, street trees, vegetation, and green streets infrastructure, emphasized in the *North Pearl District Plan*, aid in carbon sequestration. These same elements aid in the preservation of fish and wildlife habitat, a goal identified in the 2001 *Pearl District Development Plan*. The addition of street trees downtown has been particularly effective in providing habitat. In an interview, Al Solheim observed that in the days prior to redevelopment, he never noticed birds in the Pearl District, and now, there are birds everywhere (Solheim 2012).

Additional Ecosystem Services

The Pearl District incorporates other ecosystem services in addition to the four analyzed in this thesis. Through solar panels on individual buildings, and participation in a municipal composting system, energy production and waste management are integrated into neighborhood design.

BARRIERS AND AIDS TO THE INCORPORATION OF ECOSYSTEM SERVICES

Barriers

In interviews, practitioners and policy makers involved and familiar with the Pearl District identified a number of barriers that made incorporating ecosystem services into the project more difficult. The most common barrier identified was that some features of more nuanced, ecologically friendly design were inconsistent with Portland's building and zoning codes. As noted by to Don Stastny, some of the building codes in Portland were so stringent about building type and construction type that reusing existing buildings was not possible for some parcels, and developers had to start from scratch (Stastny 2012). Tearing down old buildings, and building new ones requires more energy and resources and causes additional disturbance to a landscape.

In an interview, Renee Loveland, the Sustainability Manager at Gerding Edlen, a company that has developed a number of buildings in the Pearl District, including the well known Brewery Blocks, recalled that while redeveloping Block 2, the Brewhouse and Cellar Building, one of the firm's sustainable design strategies was to reuse the tanks in the back of the brewery, where beer had been stored. Gerding Edlen wanted to use these old tanks as reclaimed rainwater harvesting cisterns (Loveland 2012). The water collected was intended to be used to flush the building's toilets. While it is now common practice in Portland for a commercial building to use reclaimed water for wastewater plumbing, at the time Block 2 was being redeveloped, this simply was not done, and the city was not ready to approve it (Loveland 2012). The tanks were still preserved, however, and one of them was used to store water in case of a fire. Using the tanks as rainwater cisterns to provide one of the Brewery Block buildings with reclaimed water would have significantly reduced the building's water consumption. Loveland observed that though Oregon has made considerable of progress in water reclamation law, this area of regulation, like other areas of environmental policy and land use regulation, is made difficult by the differing policies of many overlapping city, state, and federal jurisdictions. Attempting to find design strategies that meet the requirements of each jurisdiction can be time- and resource-intensive for developers (Loveland 2012).

Costs of development, both public and private, and financing to cover these costs, is always a barrier to creating more ecologically sustainable infrastructure and was an issue for the Pearl District. According to Stastny, the City of Portland had to be very creative about how to combine public and private funds to realize the goals of the Pearl District. One of the large components of creating the Pearl District was generating public and private partnerships for individual projects, and public improvement projects (Stastny 2012).

On the development side, project costs dictate what design strategies developers are able to incorporate into their project. Loveland declared that while cost is always a barrier when it comes to integrating sustainable design strategies into Gerding Edlen buildings, many features that can be incorporated into any building are affordable and have a short payback time. These design strategies include low-flow plumbing fixtures, hot water heater efficiency, occupancy sensors, daylight dimming controls, and energy recovery units (Loveland 2012). Gerding Edlen typically uses a LEED Silver certification as a baseline for development, because they have found that there is no incremental cost associated with design strategies to obtain this certification (Loveland 2012). There is, however, a small premium associated with LEED Gold certification. For a building to obtain LEED Gold, it may require about a one to two percent increase in development costs, depending on the goals of a project. LEED Platinum buildings are significantly more costly in design, planning, and construction costs, and are typically only attempted when project goals and budget permit (Loveland 2012). Gerding Edlen's developments in the Pearl District range from Silver to Platinum. However, despite design standard which facilitate energy savings, Loveland said that these savings cannot be ensured. In some cases, such as some of the Brewery Blocks, without being able to design a space for the needs of a specific commercial or residential tenant, buildings may not operate as efficiently as design strategies intend. This is a huge barrier to ensuring enhancement of urban ecosystem services (Loveland 2012).

All of the practitioners involved in the Pearl District who were interviewed for this study stated that there were only minor debates in the development of the neighborhood. A search of newspaper articles about Pearl District debates and controversies yielded a similar conclusion. The small debates that took place during development were minor. Early in the development, Al Solheim said, some people were upset because they believed that light industry was being pushed out of the neighborhood to make room for residential and mixed-use projects (Solheim 2012). Solheim claimed this perspective was inaccurate, and that light industry was moving out anyhow rather than being forced. Only small disputes ensued with the business association and property owners (Solheim 2012). While there were some development issues regarding brownfields and previous underground storage of industrial materials, the lack of huge social issues, such as gentrification, enabled developers to avoid major controversies (Solheim 2012).

In an interview, Mark Raggett commented that some minor debates consisted of concerns from local constituent groups that developments in the Pearl District were consuming a lot of public right of ways for ecologically friendly design strategies like stormwater treatment facilities and replacing parking and streets with better bicycle and pedestrian infrastructure (Raggett 2012). Constituent groups, according to Raggett, have some legitimate concerns about these kinds of infrastructure changes in the Pearl District. There are ongoing discussions and debates surrounding the following questions. "How much is too much? How much is the right amount? Where should we be doing it? Where should we not be doing it?" (Raggett 2012). Don Stastny stated that in Portland, nothing is done without a debate, and that major planning initiatives in Portland are usually citizen-based (Stastny 2012). Currently, the city is in the process of completing the third iteration in the lineage of central city plans, and has been at it for a considerable amount of time (Stastny 2012). "One big mistake," Stastny recalled, "was thinking they could do it within the government with citizen input, as opposed to citizen initiative" (Stastny 2012).

Aids

Policies and institutional functions that aided in the integration of ecosystem services in the Pearl District were also identified in interviews with practitioners and policy makers. One of the aids most commonly recognized was the ability to easily finance mixed-use, TOD. Since development in the Pearl District was financed by a combination of public and private investment (this varied depending on parcel, land use, and infrastructure), Stastny commented, "the idea of creating public and private partnerships for individual projects or for public realm improvements was a part of putting [the Pearl District] together" (Stastny 2012). Local banks played a key role in the financing of public and private projects, enabling TOD development to happen. Stastny stated:

> In Portland the banks and financing institutions got used to mixed-use and realized they could fund it in a way that was effective, in some ways having to piggy back different sources into a project, but realizing that this was a big part of making something happen (Stastny 2012)

Political will, and strong local private and public leadership towards sustainable development in the area, were also mentioned as the greatest aids to creating development that integrated ecosystem services. Al Solheim said that throughout development of the Pearl District, "there was a consensus on change, in retaining old buildings, and seeing the district evolve towards housing and urban services" (Solheim 2012). This strong consensus paved the way for an "active neighborhood association that provided a framework for the city and developers to have dialogue" (Solheim 2012). Development consensus also created strong leadership among property owners within the district to create partnerships to develop for the common good (Stastny 2012). According to Stastny:

> [t]here was very strong leadership by certain land owners and developers that owned land in the Pearl to maximize their holdings and there was an understanding that to maximize their holdings they had to maximize the environment around them, not just their one project (Stastny 2012)

It is likely that this public and private political will towards sustainable development of the Pearl District contributed to the ease of financing from the local banks and financial institutions.

Strong public and private support for sustainable development enabled the city to create innovative regulatory and incentive-based policies in the district to facilitate development goals. Loveland commented that the

> Portland Development Commission did come out with a lot of neat policies which targeted specific areas that the city wanted to see redeveloped. A lot of effort was placed to make that happen (Loveland 2012)

One major policy innovation was the city's willingness to adjust building codes to accommodate economically mixed-use buildings. Stastny stated that due to building costs, developers were limited to stick frame and heavy timber for some of the low-rise mixed-use buildings. In these cases, the Portland Fire Department worked with developers and changed city codes to enable the construction of buildings which allowed four stories of building frame above a concrete platform (Stastny 2012). Prior to Pearl District development, these types of buildings were not allowed. Other regulatory policies identified that aided in the ability for developers and the city to incorporate ecosystem services into design and development included Portland's lax parking requirement policies, and openness to the use of renewable energy (Loveland 2012).

Several incentive-based policies also facilitated this integration. Portland's water reclamation policy enabled another Gerding Edlen development adjacent to the Pearl District, the Twelve West building, which is designed to harvest and reuse rainwater. According to Loveland, the City of Portland allowed Gerding Edlen to pay a reduced system development charge for connecting to the sewer. While Loveland believes the city is no longer open to this incentive, she stated that it did have a very positive effect on Gerding Edlen's ability to incorporate more ecologically friendly features into their development. Portland's citywide Grey to Green program, which provides financial incentives to retrofit a building with a green roof, also encouraged Gerding Edlen to use green roofs on their projects. Small, private tax credits and development incentives also steered the direction of development. In at least one of their Pearl District projects, Gerding Edlen participated in the city's low income housing tax credit (Loveland 2012). That some of the district was designated as TIF also encouraged development. These innovative policies are reflective of the city's support of sustainable development. As Renee Loveland observed, "the design community and policy people [of Portland] are very supportive of the movement in this [environmentally sustainable development] direction."

Last, market-based demand has and continues to play a significant role in ensuring that development in the Pearl District is mixed use, pedestrian, cyclist, and ecologically friendly, and supported by transit. Stastny stated:

> Especially as it started out, the property values nor the market supported really high buildings. But as the evolvement occurred and there were more and more successful projects, it became a lot more feasible to do buildings that were 10-12 stories high and to able to finance those buildings as mixed-use buildings (Stastny 2012)

The streetcar, according to Loveland, generated much of this market-based demand for mixed-use, high-density buildings. Though the streetcar postdated much of the Pearl District redevelopment, Loveland observed, "everyone knew it was going to happen." As for development that incorporates additional ecosystem services, Solheim commented that the "marketplace for real estate development expects LEED [standards]."

MONITORING EFFORTS

Monitoring efforts are essential to determine the degree to which the Pearl District actually enhances local and regional ecosystem services. While the neighborhood design and population, and the opinions of planners, developers, and policy makers related to the district, indicate that ecosystem services are enhanced, data are needed to accurately make this determination, and to see which design strategies are most effective. At present, the city monitors very little within the neighborhood—pedestrian crossings, traffic, and streetcar ridership—with no plans for larger scale monitoring (Raggett 2012). At one time, for about five years, the City of Portland required and paid for "green" development projects that received grants, to go through post-occupancy monitoring to observe and verify the associated energy savings with green design (Loveland 2012). Gerding Edlen participated in this post-occupancy evaluation and reports revealed that the firm's projects had "either met or exceeded expectations," giving the firm a clearer idea of how their designs were functioning (Loveland 2012).

Currently, the city of Portland offers no assistance with post-occupancy studies, and the responsibility to monitor energy savings falls on developers or property owners, which makes such a process, Loveland noted, "easier said than done" (Loveland 2012). This difficulty is due, in part, to the complexity of determining where energy is being consumed for different electrical, water, and natural gas appliances in buildings with a mix of uses, such as residential and office. While monitoring these different electrical consumption rates is possible, the equipment necessary for accurate readings is costly (Loveland 2012). Even if a property owner could afford the equipment necessary to monitor a building, or if the building was simple to monitor, it is very difficult to obtain per unit data, because utility companies contract directly with tenants for electrical and gas services—information to which a landlord is not privy (Loveland 2012). The benefit of government supported post-occupancy monitoring programs is cited in Chapter 7 as an area for further research.

CONCLUSION

Today, the Pearl District is regarded as a renowned, ecologically friendly TOD. As Al Solheim remarked, "[p]eople come from all over to look at the Pearl District as a model of transportation, parks, liveablity, and walkability" (Solheim 2012). Within Portland, the Pearl District is one of the most sought after neighborhoods in which to work and reside (Franklin 2012). Since its development, numerous articles and studies have been published, in addition to reports commissioned by the City of Portland, praising the environmental efforts of the city's design and planning of the district. This has become the dominant perspective of practitioners involved with the Pearl District's planning, design, and development.

Despite its favorable TOD reputation, however, the Pearl District is not without shortcomings from an ecosystem services perspective. The analysis conducted for this thesis shows that while the Pearl District excels in providing extensive infrastructure to support alternatives modes of transportation to the personal automobile (public transit, walking, bicycling), and a diverse mix of services, housing types, and land use, the area is significantly lacking in public open space and recreational services. For the number of residents who work and reside in the area, there should be at least twice as much open space incorporated into the neighborhood. Within the existing open space and infrastructure, methods to integrate additional permeable surfaces and carbon sequestration infrastructure should be explored. Ways to make carbon sinks and existing greenspace productive places—habitats for animals and pollinators, gardens for food—also should also be considered. In addition, though the Pearl District is effective in reducing VMTs, infrastructure to aid in the processing and detoxification of the hydrologic cycle, on the neighborhood scale, though planned, has yet to be implemented.

Other criticisms of the Pearl District are unrelated to environmental sustainability. Some citizens of Portland are concerned that the area has become an enclave for the wealthy, and the average Portland resident cannot afford to live, shop, or eat there (Raggett 2012). The fear is that this trend toward unaffordability will continue to increase. Other complaints of the Pearl District include poor planning for population growth. Studies to determine whether or not a new school would be necessary to accommodate an increased number of children in the neighborhood would be necessary were never conducted (Papaefthimiou 2012). The city did not foresee that the Pearl District would attract families, but rather assumed young singles or childless couples would inhabit the area. Unexpectedly, as the population in the Pearl District increased, nearby schools became inundated with students. In 2009 discussions of a Pearl District School began taking place, and in 2011 Portland Public School (PPS) began leasing limited space for an "Early Childhood Center." However, some residents say that this new center does not meet the demand of the growing neighborhood (Anderson 2011).

Chapter 5: Seattle, Washington, South Lake Union Case Study

Context and Site Analysis

South Lake Union, also known as SLU, is one of Seattle's most rapidly changing neighborhoods. It is also quickly becoming one of city's most promising employment zones (South Lake Union n.d.). While the exact boundaries of the 340-acre (about 138 hectares) neighborhood vary depending on the source, they are generally consistent with those identified in the 2007 *Urban Center Neighborhood Plan*. SLU is bounded on the west by Aurora Avenue, on the south by Denny Way, on the east by Interstate 5, and on the north primarily by the iconic Lake Union, and Galer and Ward Streets (see Figures 12 and 13 on the following page for SLU locator maps) (DPD 2007).

Since SLU is a large neighborhood, it is sometimes broken down into the following six sub-neighborhoods for easier reference and smaller planning and design initiatives (DPD 2007):

- Dexter
- Denny Park
- Waterfront
- Westlake
- Fairview
- Cascade

See Figure 14 on page 128 for a map of these smaller neighborhoods within SLU.

Figure 12: SLU in relation to greater Seattle (South Lake Union n.d.)

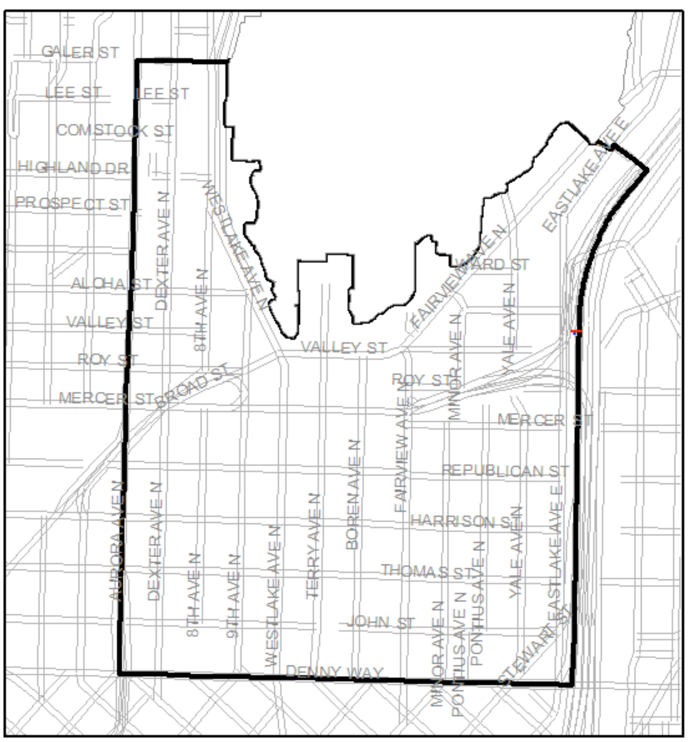

Figure 13: SLU Map (Seattle City Clerk’s Office 2012)

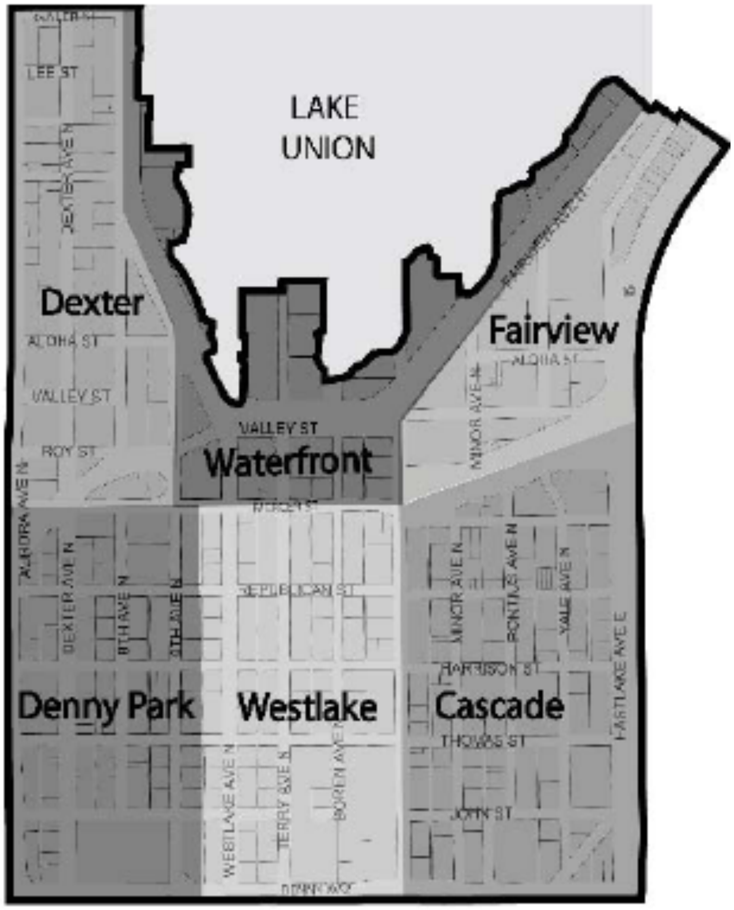

Figure 14: SLU sub-neighborhoods map (DPD 2007, 10)

In 2005, SLU was identified as an "Urban Center" under the Urban Village Strategy, outlined in Seattle's updated comprehensive plan, *Towards a Sustainable Seattle*. This designation targeted SLU as a well serviced area, where Seattle's residential population and offices could be concentrated. The neighborhood was targeted to accommodate 8,000 new households and 16,000 new jobs by 2024 (this work force estimation has since increased and is expected to be about 30,000 in the next five years) DPD 2011; South Lake Union n.d.). As an Urban Center, SLU transformed from a light industrial area that provided support to downtown offices, biotech companies, and residences, into a vibrant, mixed-use community, with amenities such as Lake Union

Park, the Seattle Streetcar, and a number of trendy shopping, eating, and entertainment opportunities. The new character of the neighborhood has attracted some of Seattle's major employers. These employers include: the Fred Hutchinson Cancer Research Center, NBBJ Architects, the headquarters for Amazon.com, Zymogenetics, and PEMCO (South Lake Union Real Estate 2011). SLU cultural and retail attractions include the Museum of History and Industry, the flagship REI store, and Whole Foods Market (South Lake Union 2012).

Figure 15: South Lake Union bird's eye view (Crane 2009)

Figure 16: South Lake Union (Cooper 2011)

Figure 17: South Lake Union view of streetcar (Scheuerman 2010)

In December 2007, the SLU Seattle Streetcar line opened (Seattle Streetcar 2007). The 2.3-mile (about 3.7 kilometers) electric rail line runs through the center of the neighborhood, providing connections to downtown Seattle and to other public transit systems such as the city and regional buses, trains, and light rail (see Figure 24 in the "Climate Regulation, Reduction of Fuel Consumption, and Air Quality Improvement" section of this chapter, for a map of the Seattle Streetcar Line) (Seattle Streetcar n.d.). The addition of the Seattle Streetcar line which services central SLU, combined with neighborhood efforts to increase density, mixed-use development, and bicycle and pedestrian infrastructure to reduce VMTs, contributes to the neighborhood's status as an up and coming Urban TOD (DPD 2007).

In addition to marketing SLU as a neighborhood with great transit amenities. Vulcan development company (the largest property owner in SLU owned by billionaire Paul Allen, co-founder of Microsoft) promotes SLU as a place for people who want to live "green," and who care about the future of the environment (South Lake Union n.d.). Vulcan's website advertises some of the green amenities of SLU—it contains the largest number of LEED buildings of any Seattle neighborhood, is being considered as Seattle's first LEED-ND neighborhood, and it has several innovative green streets projects, and transit options. Vulcan declares that in SLU, "'green isn't a marketing catchword…[i]t's a full-time, long-time serious commitment" (South Lake Union n.d.).

The information obtained for this thesis confirms that environmental goals did significantly contribute to the design and development of SLU. Planning and design practitioners involved in the neighborhood development were excited about the consideration ecosystem services, primarily stormwater quality and management, were given in the neighborhood's design. Using information obtained in interviews with practitioners who worked on the development of the SLU neighborhood, planning documents, and zoning information, the following sections in this chapter discuss the initial goals of SLU development, and how these goals incorporated ecosystem services. Further analysis using these resources will explore how ecosystem services were actually incorporated into the design of SLU. This chapter concludes with a discussion of the aids and barriers to incorporating ecosystem services into SLU's design, and the strengths and weaknesses of the neighborhood from an ecosystem services perspective.

PROJECT HISTORY AND BACKGROUND

Until 1875, it is believed that the southern boundary of SLU's Lake Union was inhabited by the Duwamish or Southern Coast Salish Native Americans (South Lake Union Real Estate 2011). Pioneer settlement of the SLU area began in 1853 with David Denny, who claimed the area known today as Denny Park as his own. As pioneers began to settle in the Seattle area, Lake Union was used to transport coal to the various settlements. In 1872 a small rail line was built to take the place of wagons for coal delivery. This railroad was short-lived, however. In 1877 service stopped and the tracks were restored to a path for wagons (South Lake Union Real Estate 2011).

The first development in the SLU area was a sawmill, built by the Lake Union and Lumber Company in 1882 on the southern shore of Lake Union (South Lake Union Real Estate 2011). Denny purchased the sawmill in 1884, changed its name to Western Mill, and expanded the operation. He cleared the land along Lake Union's southern shore and built a low lying dam so that logs from his sawmill would float to Lake Union. Lake Washington became the mills' catchment zone (South Lake Union Real Estate 2011). Denny's mill attracted employees to settle in the SLU area, and the addition of other mills located near Lake Union also encouraged settlement. Although Denny went bankrupt in 1895, his mill continued to operate under Brace & Hergert Mill Company until 1920.

Brace & Hergert, in attempts to expand their mill business, built the peninsula known today as Lake Union Park. They continued to operate other mill businesses in the SLU area until 1988 (South Lake Union Real Estate 2011).

In addition to mills, at the turn of the century the Lake Union neighborhood was home to hard industry, including manufacturing plants for: cabinetry and furniture, shipbuilding, Boeing's first airplane factory, the Lake Union Steam Plant, the Seattle City Lights Hydro House (the country's first municipally owned hydroelectric power plant), and Ford's first Model T assembly plant west of the Mississippi River (South Lake Union Real Estate 2011). In 1913, Northern Pacific Railway constructed a railroad line in the SLU neighborhood, and opened the area's first freight station. These booming industries attracted heavy residential development around Lake Union, and the area became a housing center for European immigrants (South Lake Union Real Estate 2011).

Beginning in the 1930s, SLU transitioned away from a residential center into a predominantly commercial area with small businesses, auto dealerships, and warehouses. The neighborhood stayed in a similar state until redevelopment. Until the late 1990s, South Lake union provided essential support services to downtown Seattle and nearby biotech companies (South Lake Union Real Estate 2011).

The campaign for redevelopment of SLU began in the early 1990s with the city's plan for a 61-acre (about 24.7 hectares) public park, called the "Seattle Commons," reaching from downtown Seattle to Lake Union. Paul Allen agreed to develop the Commons in partnership with the City of Seattle. Allen, under his development company Vulcan, acquired $30 million in property for the park, with an agreement that the city would pay him back once the measure was approved by voters to develop the Commons. The Commons measure went to vote twice, in 1995 and 1996, and failed both times. The property purchased by Vulcan for the city was returned to the development company, who began developing individual parcels around 2003, as it was clear that SLU would soon be designated an Urban Center in the 2004 Seattle Comprehensive Plan (Morgan 2012).

Since 2003, the same year the SLU streetcar was proposed by Mayor Nickels, over $2 billion of private investment has been directed to SLU, and development has soared. The area has seen the addition of more than 2,300 residential units, two million square feet (about 108,806 square meters) of office, retail, and biotech laboratories, and 12 acres (about 5 hectares) of city park, named Lake Union Park (South Lake Union n.d.; South Lake Union Real Estate 2011). Two million square feet of additional office and retail space currently is under construction. The streetcar, which today services up to 3,000 people on a weekday, was approved in 2005 and began operations in 2007 (see Figure 18 below for streetcar ridership graph) (Seattle Streetcar n.d.; Parast 2011). The neighborhood continues to attract significant employers, most notably Amazon, which began tenancy in its SLU campus in 2010 and has plans to acquire an additional street block in the near future (Morgan 2012).

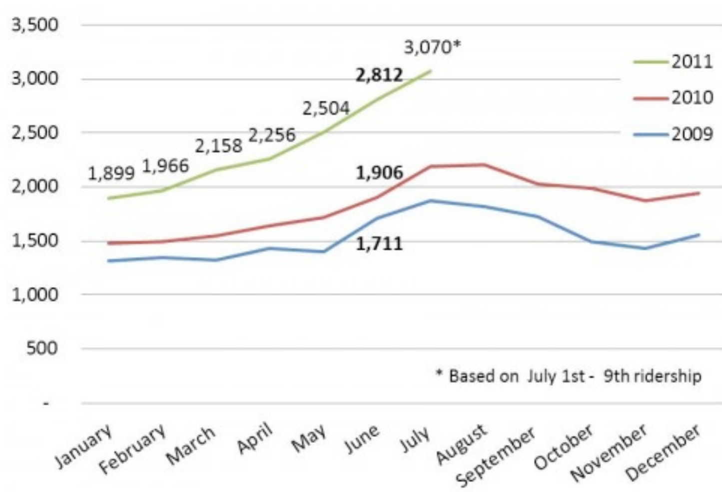

Figure 18: SLU streetcar average weekday ridership (Parast 2011).

Development of SLU has been a collaborative effort between all major private property owners—Vulcan (the majority property owner who holds title to between 30 to 50 percent of SLU real estate), Reel Investors, *The Seattle Times*, and Pemco—and the City of Seattle (see Figure 19 on the following page for a map of parcels by owner). Financing mechanisms utilized for SLU include private funding for individual developments, public funding for city infrastructure such as city parks, new power systems, and stormwater infrastructure, and a combination of public and private funding for the Seattle Streetcar (Morgan 2012; Bicknell 2012). To help finance public costs, SLU was designated as a local improvement district (Whitson 2012). While full buildout of the neighborhood is not expected until 2024, SLU is quickly becoming Seattle's most "green" neighborhood, and the most popular area in the city to live, work, and play.

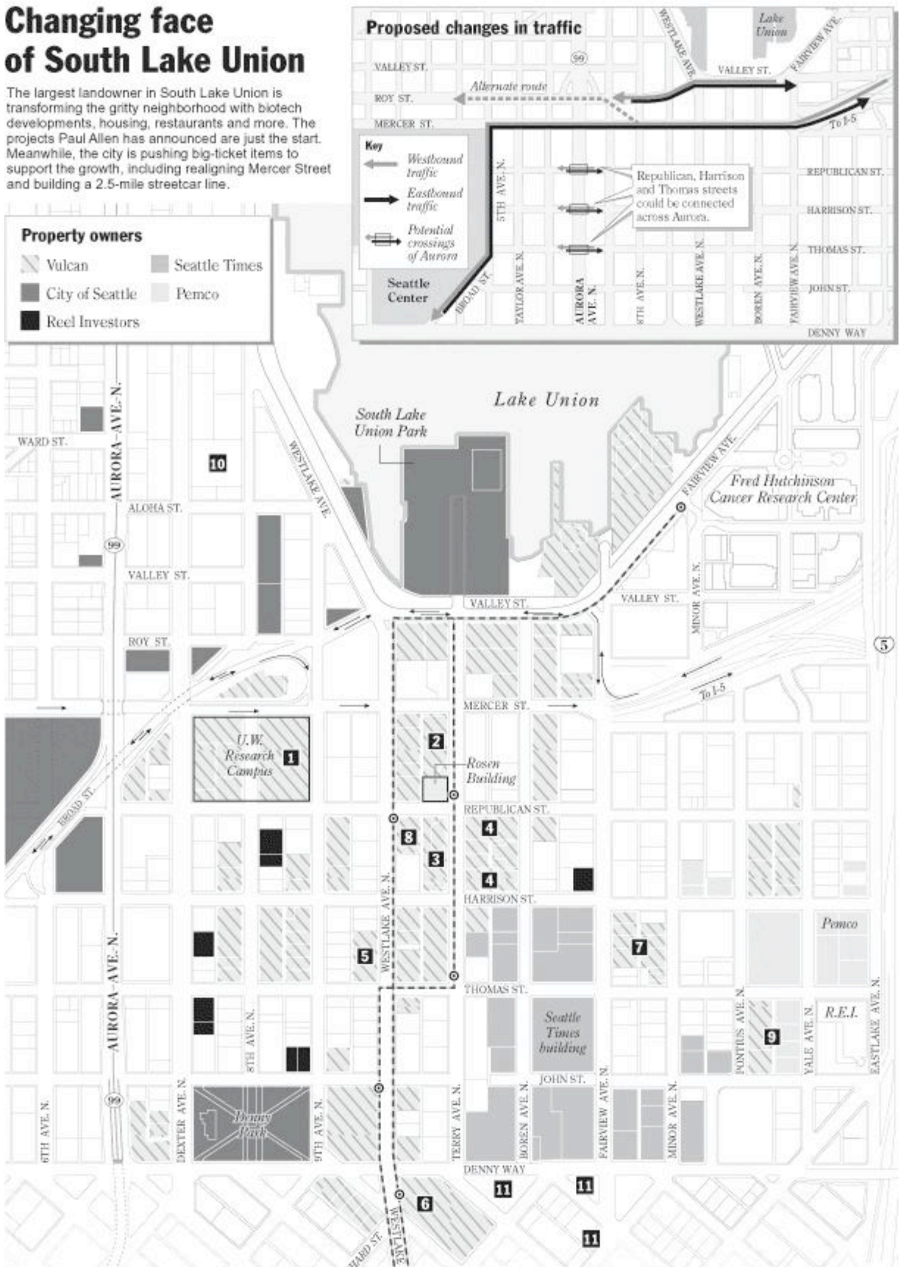

Figure 19: Large property owners of SLU (Seattle Displacement Coalition 2004).

The following plans have been most integral in the redevelopment of SLU as a transit-oriented, residential and employment district:

- *Toward a Sustainable Seattle* (1994)

- *South Lake Union Neighborhood Plan* (1998)
- *Resource Guide for Sustainable Development* (2002)
- *North Downtown Plan* (2004)
- *Seattle's Comprehensive Plan* (2004)
- *South Lake Union Design Guidelines* (2005)
- *Terry Avenue North Street Design Guidelines* (2005)
- *Urban Center Neighborhood Plan* (2007)
- *South Lake Union/Uptown Triangle Mobility Plan* (2011)

In the following section of this chapter, these plans, and information obtained from interviews with planning and design practitioners involved with SLU, are analyzed to determine the initial development goals behind the neighborhood, and how these goals incorporated ecosystem services into neighborhood design.

GOALS, DESIGN, AND ECOSYSTEM SERVICES

Goals According to Plans and Practitioners

According to Lish Whitson, a former planner for the City of Seattle and the Project Manager for the South Lake Union 2007 *Urban Center Neighborhood Plan*, some of the initial goals of SLU development were not transit, but rather "to help create a consensus among neighborhood stakeholders for how the neighborhood could accommodate the amount of growth that was expected for the area" and to a build a central biotech employment district within Seattle (Whitson 2012). Whitson stated that ecosystem services, though alternatively referred to as environmental benefits, were explicitly incorporated into design goals at the outset of SLU planning. Water quality and the reduction of pollutants in Lake Union were specifically considered in the development of Lake Union Park, and increasing natural stormwater management systems to improve SLU's drainage and stormwater quality were considered in neighborhood design (Whitson 2012). Other design practitioners noted that while one of the primary goals was to create a compelling, mixed-use neighborhood, where one could "live, work, shop, and eat, that had all of the necessary amenities, like open space," environmental sustainability was not explicitly on the radar (Bicknell 2012). Lyle Bicknell, a Principal Urban Designer in Seattle's Department of Planning and Development, said that though not explicitly stated, environmental sustainability was inherent to the initial goals of SLU as a dense, mixed-use development:

> Inherent to [the goals stated by Bicknell above] is a sustainability and environmental goal. Neighborhoods that are denser, neighborhoods where you don't need to get into your car to meet everyday needs, neighborhoods where you can walk to work or where there are convenient transit options, those, in my mind, are inherently sustainable. I think that was part in parcel to our goals in SLU (Bicknell 2012)

According to planning documents, enhancing Seattle's natural environment, not explicitly called ecosystem services, has been a central goal to the development of SLU since the 1990s. As previously stated, Seattle's 1994 comprehensive plan, *Toward a Sustainable Seattle*, was the first plan to target the area for significant redevelopment. The plan sought to accommodate over 1,700 additional residences and 4,500 jobs within the neighborhood over the next 20 years, by utilizing the now well-known "Urban Village Strategy" (DPD 2007). In the Urban Village Strategy, a series of neighborhoods within the city were identified as "Urban Villages" (also called Urban Centers). An Urban Center was defined as an area where development could be concentrated to accommodate Seattle's growing population and job growth, which had implications for a better natural environment, another central goal of the plan (DPD 2005). By identifying Urban Villages early on, it was believed that the city would be at an advantage to target areas for additional improvements in environmental quality such as air and water, and urban infrastructure like better pedestrian infrastructure, a greater mix of land uses in proximity to one another, and better public transit systems (DPD 2005). Dense Urban Villages were also practical for Seattle, as a city in King County, because since 1985 King County had implemented an "urban growth boundary line" (DDES 2012).

While SLU was not identified as an Urban Village in 1994, it became an Urban Village in 2005, in the updated version of *Toward a Sustainable Seattle*. The updated version identifies "Environmental Stewardship" as a core value adopted by the city, serving as "the fundamental principles that guide the Comprehensive Plan and the ultimate measure of its success or failure" (DPD 2005, v). The plan identifies the urban centers concept as one of the city's strongest strategies to benefit the natural environment. The plan states:

> The urban village concept promotes compact, more pedestrian-oriented development and alternative (non-auto) transportation choices such as transit, as well as incentive and disincentive programs to encourage getting around without a car. The emphasis on compact development is intended to mitigate air and stormwater discharge pollution from automobiles, loss of green space, and increase impervious surfaces that results from non-compact development (DPD 2005, vi)

Specific goals identified in the plan for SLU environmental stewardship included (DPD 2005):

- Neighborhood adoption of sustainable redevelopment practices.
- Increasing accessibility desirability of parks and open space to residents.
- Encouraging low-impact development techniques (LID).
- Exploring sources of renewable energy to supply the neighborhood.
- Reintroducing tree and other native plant species into SLU for additional shade coverage and animal habitat.

The incorporation of environmental design strategies into SLU to enhance the natural environment predates its designation as an Urban Center. In 2002, Vulcan commissioned the Urban Environmental Institute (UEI) to create a resource guide for all developers which provided market appropriate development strategies to be used for sustainable development. SLU was used as a case study for this report, and was identified as a model for environmentally sustainable development. Suggestions for more environmentally sustainable development ranged from recycling materials in the construction process to sharing water and energy infrastructure between buildings (UEI 2002). The concept of ecosystem services is explicitly mentioned only once in this plan, when referring to new technology available for environmental analysis (UEI 2002).

The 2004 *North Downtown Park Plan* provides recommendations for design strategies for neighborhood amenities, necessary to meet the city's goals of transforming the SLU area "into a high-intensity district including one of the nation's leading biotech centers, office complexes, diverse urban neighborhoods, and supporting commercial activities" (MAKERS et al. 2004, 1). These suggested design strategies include the incorporation of ecosystem services (though this term is not identified anywhere in the report) such as: additional acres of parks, trails, open space, community gardens, and recreational facilities, and VMT reducing mechanisms like integrated street, pedestrian, and bicycle infrastructure (MAKERS et al. 2004, 1). The 2005 *Terry Avenue North Street Design Guidelines* and *South Lake Union Design Guidelines* provide street, sidewalk, and bicycle infrastructure design specifications to implement the goals outlined in the North Downtown Plan. In addition, both plans provide specific design guidelines for natural stormwater management.

Of the recent SLU plans, the 2007 *Urban Center Neighborhood Plan*, updated from the 1998 *South Lake Union Neighborhood Plan*, has been the most influential. In accommodating the 16,000 new jobs and 8,000 new households over the next 20 years, as proposed in *Toward a Sustainable Seattle*, the plan identifies the following five neighborhood development priorities (DPD 2007):

- Neighborhood Character
- Transportation
- Parks and Open Space
- Housing
- Sustainable Development

Of these five priorities, transportation, parks and open space, and especially sustainable development, incorporate enhancing ecosystem services into the design of SLU, though again, the term ecosystem services is not used anywhere in the plan.

While the transportation and parks and open space priorities refer to enhancing SLU's ecosystem services, the sustainable development priority provides the most significant design strategies to enhance SLU's natural environment. These strategies include (DPD 2007):

- Using LID methods for natural stormwater management, increasing use of native plans and vegetation.
- Encouraging greenroofs and green walls.
- Creating coordinated energy systems between buildings for conservation.
- Encouraging the construction of LEED buildings.

The 2010 *South Lake Union Urban Design Framework* provided the design specifications to meet the goals outlined in the *2007 Urban Center Neighborhood* plan. Significant design specifications in this plan which enhance ecosystem services include policies to create an extensive natural stormwater management system throughout SLU and development bonuses for upzoning to encourage neighborhood density (DPD 2010).

The most recent SLU specific plan, the 2011 *South Lake Union/Uptown Triangle Mobility Plan*, provides suggestions to further reduce VMTs, such as increasing street and neighborhood connectivity, and pedestrian, bicycle, and public transit infrastructure (Heffron Transportation et al. 2011).

The series of SLU planning documents and the information obtained from interviews with practitioners illustrate that while the concept of "ecosystem services" has not been explicit in the development of SLU, planning for the enhancement of these services has been a central goal in all major plans for the area. The following section explores how ecosystem services have actually been integrated into the design of SLU.

Ecosystem Services According to Plans and Practitioners

SLU meets Calthorpe's criteria for an infill/redevelopable Urban TOD: it is a dense, mixed-use neighborhood, consisting of both infill and redeveloped buildings, located next to downtown, and is serviced by a streetcar. Like Portland's Pearl District, SLU is a neighborhood that consists of multiple transit stops.

Climate Regulation, Reduction of Fuel Consumption, and Air Quality Improvement

Seattle practitioners and policy makers all commented that natural stormwater infrastructure was the ecosystem service given the greatest consideration in the development of SLU. They also agreed that the addition of transit, pedestrian, and bicycle infrastructure into the neighborhood has, and will have, a significant impact local ecosystem services by assisting in VMT reduction. Lyle Bicknell remarked that he believes there is a "night and day difference" between the old and new SLU. Whereas people used to just go quickly through the neighborhood to get to another destination, SLU is now active with pedestrians and cyclists. People are riding the streetcar, there is less auto traffic, and the streets feel more comfortable (Bicknell 2012).

This increase in activity is due in part, to the mix of uses now located in the neighborhood. The land uses in SLU are as follows (see Figure 20 below for a SLU zoning and height map):

- Seattle Mixed (SM), which allows for a mix of residential and non-residential uses.
- Seattle Mixed/Residential (SM/R), which is similar to SM but encourages residential development.
- Industrial Commercial (IC), allows a mix of industrial and commercial uses but no residential.
- Commercial 2 (C2), which allows more intense, auto-oriented commercial activity.

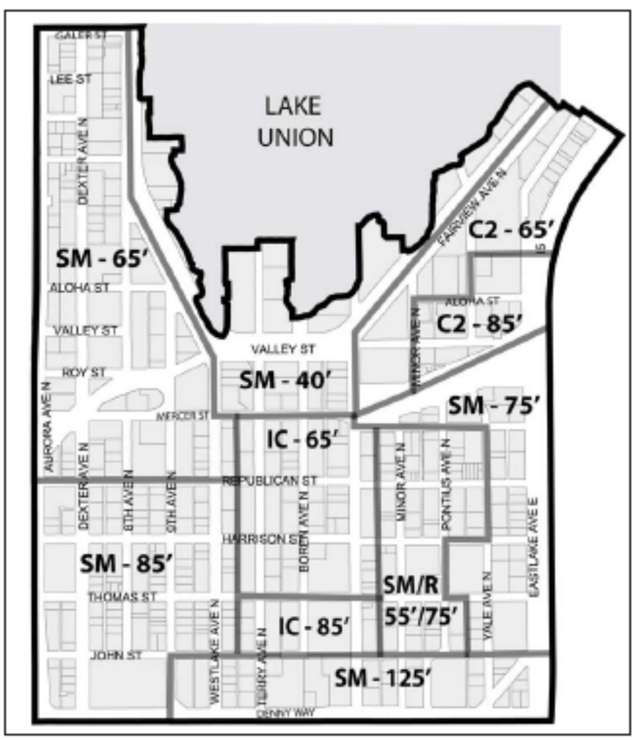

Figure 20: SLU zoning and height map (DPD 2007, 12)

Figures 21 and 22 below show the composition of land uses in SLU, from pre-development in 1998 to about three years into redevelopment, in 2006. These pie charts show that about seven percent of SLU is housing, 62 percent is commercial and employment (the sum of office/biotech, retail/service, and industrial/warehouse), and 12 percent is public (DPD 2007). The percentage of commercial, employment, and public space in SLU is consistent with the mix of uses suggested by Calthorpe for a successful urban TOD—30 to 70 percent commercial and employment and five to 15 percent public (Calthorpe 1993). The percentage of housing, however, at seven percent, is significantly lower than the 20 to 60 percent housing recommended by Calthorpe. Given the projected growth of the area, it is believed that this percentage of housing will increase significantly. From 2004 to 2009 alone, housing units in SLU increased by more than 1,000 units, from 1,306 units to 2,940 units, respectively (DPD 2010). At full buildout in 2024, it is projected that SLU will have 9,306 housing units and 35,690 jobs. That is, the ratio of housing units to jobs will be about one to four, or 25 percent (DPD 2010).

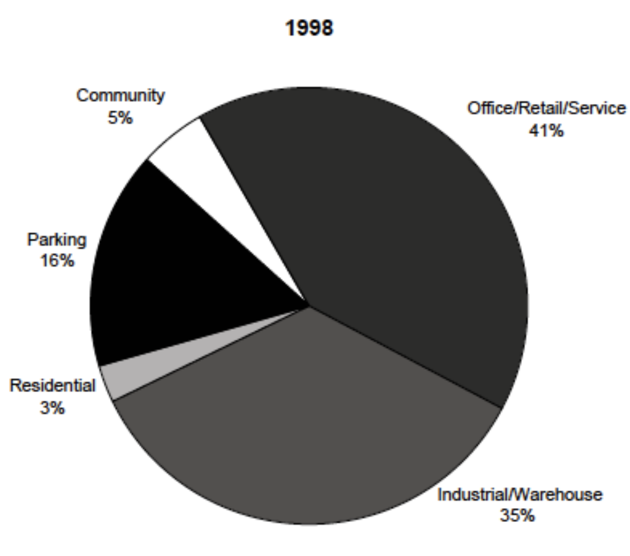

Figure 21: 1998 percentage of SLU land uses by parcel area (DPD 2007, 13)

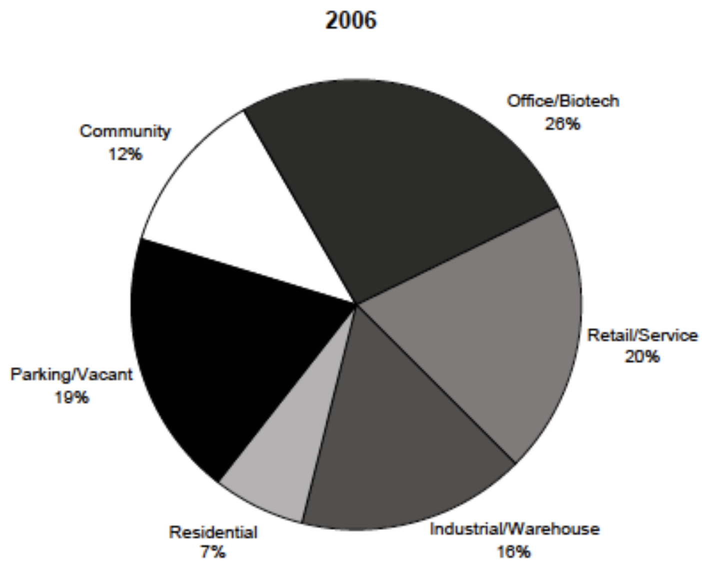

Figure 22: 2006 percentage of SLU land uses by parcel area (DPD 2007, 13)

Consistent with Calthorpe's design guidelines, the mix of SLU land uses is integrated. Any given block in SLU consists of a variety of land uses—housing (the majority of which is multi-family), business, retail, and commercial—all located near greenspace (see Figure 23 on the following page for a land use map). Buildings in SLU also are consistently mixed-use (mixed-use has been integrated more into SLU since 2002, when Figure 23 was published), as suggested by Calthorpe's design guidelines.

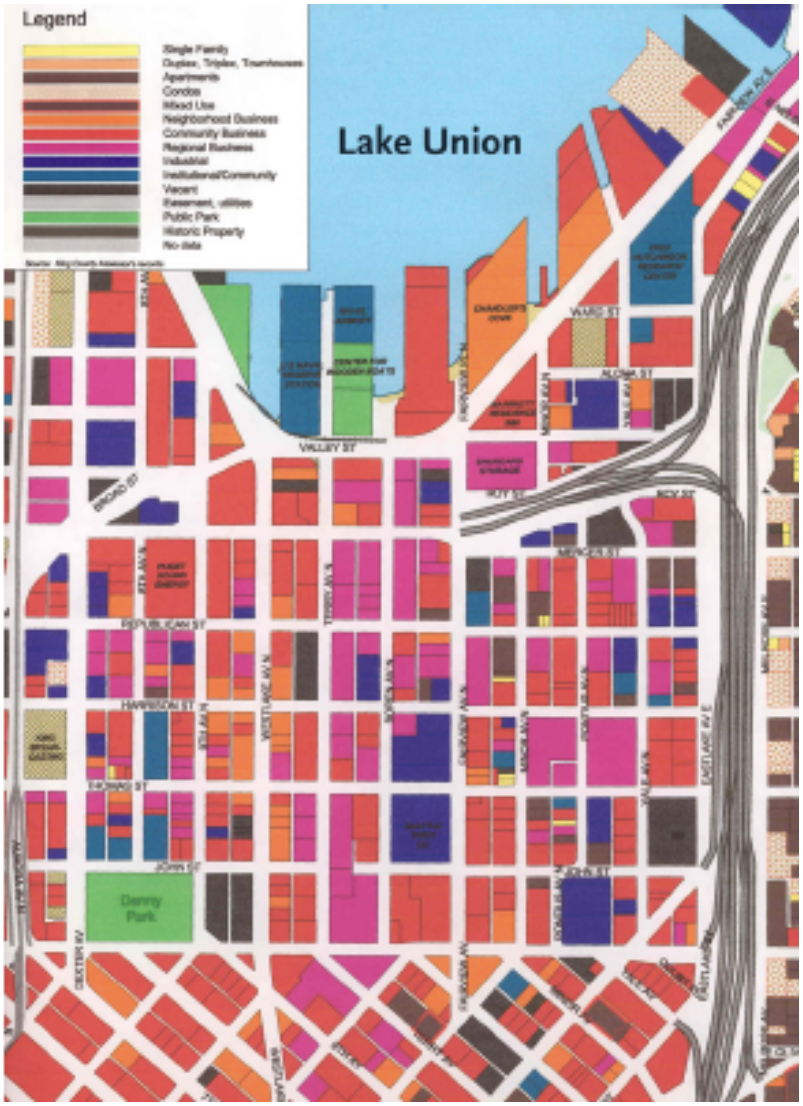

Figure 23: SLU land uses by parcel (UEI 2002, 45)

In 2009, the residential density of SLU, at 340 acres (about 138 hectares) with a population of 2,940 housing units, was about eight dwelling units per acre (DPD 2010). At full buildout, with 9,306 housing units, the residential density of SLU will be about 27 residential units per acre (about 0.4 hectares) (DPD 2010). This residential density far exceeds Calthorpe's suggested minimum of between 10 and 25 units per acre (about 0.4 hectares), required to support transit systems and retail and commercial land uses to effectively reduce VMTs (Calthorpe 1993). It should be noted, however, that the housing types in SLU lack diversity, and consist of predominantly multi-family apartments and condos, and only a few duplex townhouses. This lack of housing diversity is inconsistent with Calthorpe's recommendation for diverse housing types.

The Seattle Streetcar has a total of 11 stops, only seven of which are located within SLU, and one directly outside the southern border at Denny Way. There are four stops for each direction (north and south). On average, stops are located about 0.4 miles (about 0.6 kilometers) distance from one another, and about 0.5 miles (about 0.8 kilometers) to the east and west neighborhood boundaries (see Figure 24 on the following page for a map of the streetcar route and stops). From within SLU, the greatest distance a resident would need to walk to access a streetcar stop would be about a half mile (about 0.8 kilometers), or 2,640 feet (about 805 meters). This maximum significantly exceeds the 2,000 foot (about 610 meters) maximum suggested by Calthorpe (Calthorpe 1993). While there are other primary public transit systems in the general vicinity of SLU, such as Seattle's monorail and light rail, these systems are located miles away, and therefore are not within a reasonable walking distance (see Figure 25 on page 129 for a map of these other transit options).

Figure 24: Map of Seattle Streetcar SLU line route and stops (Seattle Streetcar n.d.)

Figure 25: (SDOT et al. 2005, 11)

The Seattle Streetcar runs every 15-minutes during operating hours, which is Calthorpe's suggested frequency (Seattle Streetcar n.d.). After receiving a $65,000 grant from Seattle's four largest employers—Amazon, the Fred Hutchinson Cancer Research Center, the University of Washington, and Group Health Cooperative—the city announced a one year pilot project that will provide a streetcar every 10-minutes during peak hours (Gutierrez 2011). As can be seen in the Streetcar Ridership Map (Figure 18 in the "Project Background and History" section of this chapter) streetcar ridership is rapidly increasing (Parast 2011). In 2011, average ridership exceeded 3,000 passengers per weekday, and the Seattle Department of Transit reported that monthly ridership in April 2011 increased 38 percent above the previous year (Gutierrez 2011). An extensive streetcar network has been planned for future development. The newest line will be a two-mile (about three kilometers) expansion to service First Hill and Captiol Hill neighborhoods, and Seattle's Chinatown/International District (see Figure 26 for Seattle's future planned streetcar lines) (Seattle Streetcar n.d.). The First Hill Line is expected to begin operating in 2013 (Seattle Streetcar n.d.).

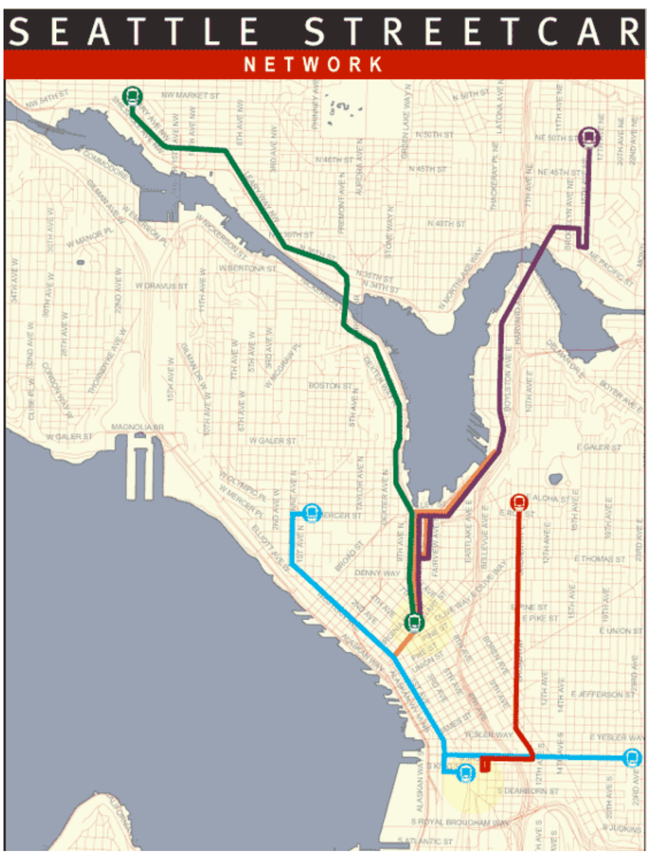

Figure 26: Seattle's planned streetcar network (Seattle Streetcar n.d.)

At full buildout, SLU will have excellent bicycle pedestrian, and street connectivity, consistent with Calthorpe's TOD design guidelines. Presently, the Mercer Corridor Project, a project to increase street beautification and efficiency, has caused the closure of significant SLU arterials. Most significantly, this project has forced the 80,000 cars which drive along Mercer East daily to reroute, causing serious disruption to vehicle, pedestrian, and bicycle traffic in SLU and nearby areas (Ellsworth 2012). The Mercer Corridor Project will continue to disrupt SLU traffic through 2013 (SDOT 2012).

When complete, however, SLU will be an easily navigable neighborhood for automobiles. The street grid is small and well connected, both to internal destinations, and external destinations like Downtown Seattle, the University of Washington, and the Space Needle. The ratio of existing off street parking to on street parking in SLU remains high. In 2004, it was estimated that there existed 10,681 off-street parking spots and 3,600 on-street parking stops (SDOT 2004). The city has publicly recognized that parking requirements in SLU must be more stringent, or "the neighborhood could see up to 13,000 more vehicles coming to the neighborhood each day by 2025" (DPD 2007, 48). Consistent with Calthorpe's design guidelines, the city has made policies to encourage on-street parking in SLU and reduce off-street parking requirements, to avoid open space parking lots in particular. Where open parking lots cannot be avoided, shared parking is encouraged (DPD 2007). The city has also has made an effort to share on-street parking and residential parking (SDOT 2007). Zipcars (car sharing vehicles) and electric vehicle charging stations have also been integrated into SLU, to assist in more sustainable single occupancy vehicle activity (South Lake Union n.d.).

Though advertised as a bicycle-friendly community, SLU has yet to construct adequate bicycle infrastructure for commuting. While commuters and residents are allowed to bring bicycles on the streetcar and buses, and the City of Seattle's major north and south bike routes go through SLU, there are no major east and west bicycle lanes within the neighborhood (See Figure 27 below for a current SLU bike map) (South Lake Union n.d.). All SLU plans emphasize adding more bike lanes and bike parking to the neighborhood, but as SLU is now, bicycle infrastructure is inadequate, and is therefore not consistent with Calthorpe's TOD design guidelines.

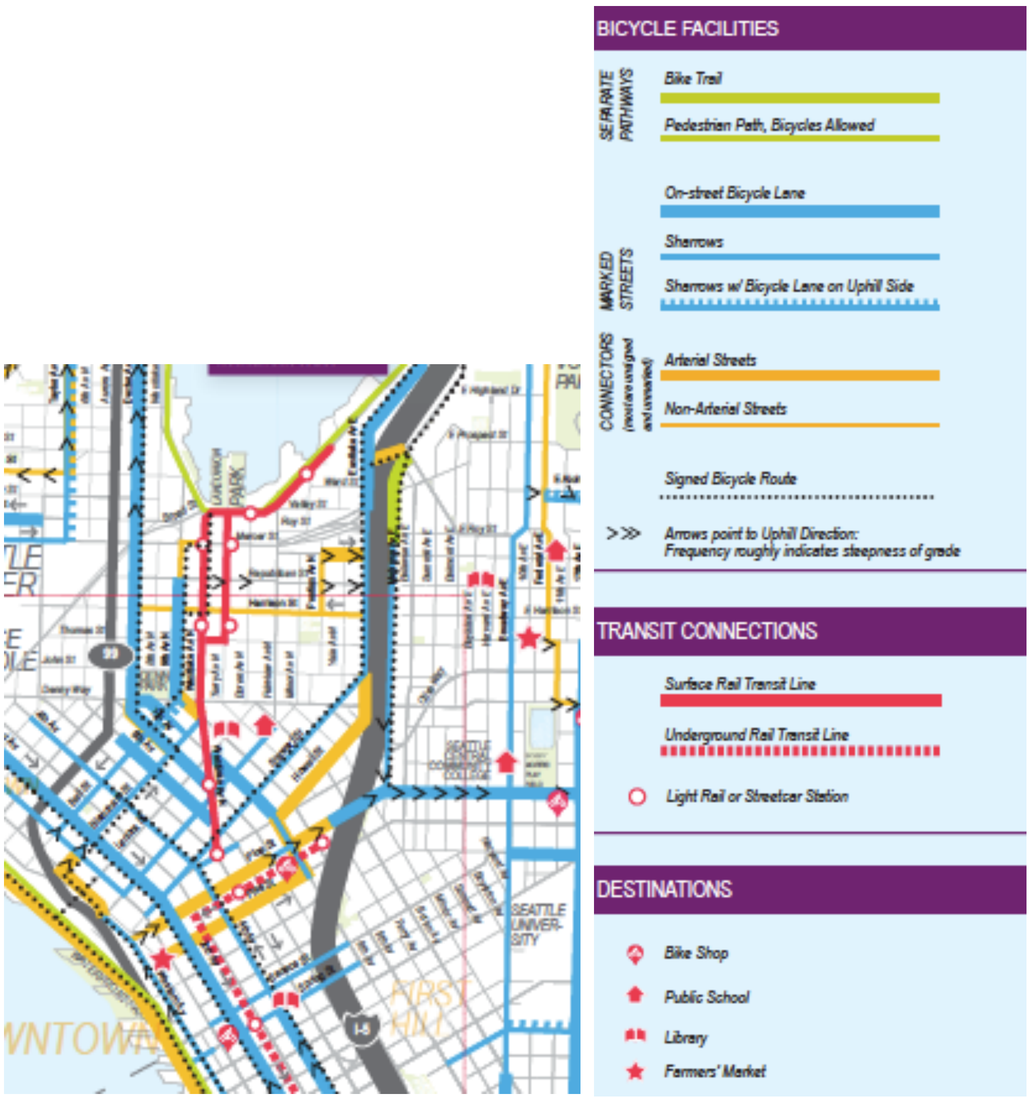

Figure 27: SLU Bike Map (SDOT 2011)

Pedestrian-friendly infrastructure, identified by Calthorpe as an essential TOD element, is emphasized more significantly in SLU than bicycle infrastructure. SLU is one of the 15 city neighborhoods participating in the City of Seattle's Green Streets program. A "green street" is defined by the city as:

> [A] street right-of-way that, through a variety of design and operational treatments, gives priority to pedestrian circulation and open space over other transportation uses (SDOT 2011)

SLU's 2005 *Terry Avenue North Street Design Guidelines* have been adopted by the city as appropriate for SLU's green streets design guidelines. Design guidelines proposed in this plan to increase pedestrian infrastructure and enhance the walking experience in SLU include (SDOT et al. 2005):

- Adding buffer zones on the sidewalk between the pedestrian and road. such as street trees, street furniture, green space, or street lights.
- Increasing sidewalk width, particularly at intersections.
- Utilizing attractive sidewalk materials such as brick, stamped concrete, or granite.
- Encouraging angled on street parking.
- Increasing street lighting.
- Increasing street trees and vegetation for aesthetics and natural stormwater management.

Most streets in SLU have sidewalks, and the pedestrian experience has been greatly enhanced on streets which have been redeveloped according to the green streets design guidelines. On these redeveloped sidewalks, there have been noticeable additions of green pedestrian buffers, rain gardens, and street trees. That being said, however, many sidewalks in SLU remain barren and not conducive to a pleasant pedestrian experience

(DPD 2010). As the neighborhood redevelopment continues, it is expected that these sidewalks will be replaced with more pleasant, green streets infrastructure (SDOT 2011).

Energy conservation and efficient building design, a TOD design guideline identified by Calthorpe, also have been incorporated into SLU neighborhood design. SLU has the largest concentration of LEED certified buildings of any Seattle neighborhood, including the nation's first LEED Silver building, the Seattle Biomedical Research Institute (South Lake Union n.d.). In the most recent SLU design guidelines, encouraging LEED buildings, and the creation of energy districts between buildings to utilize waste energy have been emphasized (DPD 2010).

Hydrology and Carbon Processing and Detoxification, Increased Urban and Rural Open Space, Urban Recreational Services, and Preservation of Habitat

As suggested in Calthorpe's design guidelines, enhancing the water quality and habitat of nearby Lake Union was a primary goal in the development of SLU (Whitson 2012). Therefore, maximizing natural infrastructure to manage the neighborhood's hydrology ecosystem service is strongly reflected in the design of SLU. Additionally, in 2009, amidst SLU planning and design, the City of Seattle adopted Seattle Municipal Code (SMC) 22.800-22.808, which "requires projects to implement green stormwater infrastructure (GSI) to the maximum extent feasible (MEF)" (SPU 2009). The following methods of GSI were recommended for SLU in *South Lake Union Urban Design Framework*. These methods are consistent with the city's adoption of GSI, and SLU's participation in Seattle's green streets program (DPD 2010):

- Bioretention plantings.
- Permeable paving.
- Green roofs.
- Rainwater harvesting.

Also identified were areas of the neighborhood which would be most appropriate for GSI infrastructure. The addition of these LID techniques is apparent on many of the redeveloped streets within the neighborhood, providing aesthetic benefits in addition to environmental benefits. As the area continues to develop, additional natural stormwater infrastructure will be added to both public infrastructure (parks and public right of ways), and private buildings (LEED and Living Buildings) in accordance with the city requirements.

In interviews, the most commonly identified natural stormwater infrastructure discussed was the "Swale on Yale." The Swale on Yale, currently under construction, is a natural stormwater management project sponsored by Seattle Public Utilities, with support from developers. The majority of the project is located on Yale Street (Morgan 2012). It consists of the following stormwater infrastructure to divert 190 million gallons (719,228,239 liters) of polluted stormwater annually from Lake union (SPU 2011):

- Four large biofiltration swales (270 feet by about 10.5 to 16.5 feet—about 82.3 meters by 3.2 by 5 meters) to filter pollutants out of water before discharging into Lake Union.
- A diversion vault, an underground tank which directs stormwater water towards the biofiltration swales.
- A swirl concentrator, a large piece of underground equipment which spins the stormwater, creating a vortex which separates solids into a separate container.
- 2,000 feet (about 610 meters) of new storm drain to direct untreated stormwater into the swirl concentrator, diversion vault, and biofiltration swales. Treated water will also be directed to Lake Union via storm drain for discharge.

Further research revealed that the Swale on Yale is not a part of SLU, but rather a component of the Capitol Hill Water Quality Project. It was included in this analysis, however, because it aids in the enhancement of South Lake Union's hydrology and habitat preservation ecosystem services.

Other habitats, in addition to Lake Union, continue to be enhanced and conserved in the development of SLU. The ongoing addition of native trees and vegetation, consistent with Calthorpe's design guidelines and mandated by SLU's adoption of the City of Seattle's Green Streets program, has increased potential urban habitat for birds and insects. Additionally, the development of SLU as an urban center where residential and office employment is concentrated, reduces sprawl and therefore perseveres rural and open space. The implementation of a UGB, recommended by Calthorpe, encourages this open space and habitat saving type of development.

SLU parks and open space also provide additional habitat and permeable surfaces for stormwater infrastructure in the urban environment, as well as providing the recreational opportunities. SLU has the following three parks:

- Denny Park
- Cascade Playground
- Lake Union Park

Denny Park, with an area of 4.63 acres (about 1.87 hectares), is the oldest park in Seattle. It is located in on the northern boundary of the central business district, and consists of paths, an area for off-leash dogs, a play area for kids, and a well established tree canopy (Seattle Parks and Recreation 2011). Denny Park is a convenient place for passive recreation—to take a lunch break or walk a dog.

Cascade Playground has an area of 1.9 acres (about 0.8 hectares), and includes space for both active and passive recreation. In addition to a half basketball court, two play areas, and a large recreational field, Cascade Playground has picnic tables and is adjacent to a community garden, called a "p-patch" in Seattle (Seattle Parks and Recreation 2011).

Lake Union Park, which opened September 25, 2011, has an area of 12 acres (about five hectares). It is the largest and most recent SLU park. Lake Union Park offers cultural services in addition to recreational services. It surrounds the Museum of History and Industry, sits on the shore of Lake Union and adjacent to a historic ships wharf, includes a model boat pond and art instillation, and offers access to several boating and maritime heritage programs (Seattle Parks and Recreation 2011). For passive recreation, Lake Union Park has walking paths, a fountain, and greenspace. The Cheshiahud Loop, a shared hike and bike trail currently under construction, will be one of SLU's main amenities for active recreation, and will be connected to Lake Union Park (Seattle Parks and Recreation 2011).

In total, there are about 18.5 acres (about 7.5 hectares) of public green space acreage in SLU, comprising over five percent of the total 340 acre (about 138 hectares) site area. This area is consistent with Calthorpe's recommendation of five to 10 percent green space per individual TOD. Lake Union Park, at 12 (about five hectares) acres, also is consistent with Calthorpe's design guideline for a large neighborhood park with recreational amenities. At full buildout with 8,000 household units, and an average of 2.25 people per household, SLU will have a residential population of about 18,000 (DPD 2000). While there will be a little over one acre (about 0.4 hectares) of open space per thousand population at full buildout, consistent with the City of Seattle's goals, this is considerably less than Calthorpe's guideline of 3.5 acres (about 1.4 hectares) per thousand population (Calthorpe 1993).

Cumulatively, all of the green streets, natural stormwater, and parks infrastructure aids in the carbon sequestration, and the ecosystem service of local and global climate regulation. In the plans for SLU, there is no mention of carbon sequestration, though practitioners commented that they believe this was inherent in the incorporation of a streetcar and additional design features aimed at reducing VMTs.

Additional Ecosystem Services

In addition to the four ecosystem explored in this paper, SLU incorporates food production and waste management into neighborhood design. Included in Cascade Playground is a p-patch community garden, where any resident who would like to garden may use a plot. SLU also participates in Seattle's "Waste Zero" program, which offers municipal composing for waste reduction. Cultural services, considered an ecosystem service in the Millennium Ecosystem Assesment, are also available in SLU's Lake Union Park.

BARRIERS AND AIDS TO THE INCORPORATION OF ECOSYSTEM SERVICES

Barriers

The most common barrier to integrating ecosystem services into SLU neighborhood design that was identified in interviews with practitioners was public objection to growth and change in the area. Mahlon Clements explained that one of the most controversial issues during the initial planning of SLU surrounded building height. This continues to be a contentious issue today. Seattle's planning agency and citizens, in general, tend to have an aversion to taller buildings, and especially to the addition of taller buildings in neighborhood areas. This aversion, Clements commented, leads to:

> frustration by a lot of urban design professionals and planners--on the one hand [the City and people of Seattle] want to create a sustainable city but don't want to do the things that are needed (Clements 2012)

An article in *The Seattle Times* reveals the details surrounding the ongoing building height debate. At the outset of planning for SLU, Seattle Mayor Greg Nickel's (whose term has since expired) sought to allow building height increases throughout the neighborhood from 65 to 85 feet (about 20 to 26 meters), and from and 85 to 105 feet (about 26 to 32 meters) (Young 2003). While zoning changes in building height were ultimately granted to some areas to accommodate growth, Vulcan has recently petitioned the city for even greater height increases. According to an article in *The Seattle Times*, SLU "building heights could rise from the current 65 to 125 feet [about 20 to 26 meters] to as much as 240 to 300 feet [about 73 to 91 meters]" (Heffer 2010).

For both public and private development, high costs associated with the utilization of more environmentally sustainable infrastructure limited the degree to which ecosystem services could be integrated into SLU's design. Lyle Bicknell stated that the redevelopment of SLU had been under enormous scrutiny by *The Seattle Times* since the project's inception. The newspaper claimed that the project was never going to work, and was an inappropriate act by the city of "throwing money at Vulcan's pipe dream" (Bicknell 2012). While *The Seattle Times* now trumpets SLU's success as a great innovation and example of city building, Bicknell stated that not having the support of the local paper during the height of neighborhood design and implementation, "made it very hard to put any public money towards environmental sustainability" (Bicknell 2012).

On the private development side, high costs limited the number of LEED Platinum certified buildings that Vulcan was able to develop in the neighborhood. Brandon Morgan of Vulcan commented that while there are virtually no additional costs for developing LEED standard certified and LEED Silver buildings, and the premium associated with LEED gold is about two percent, LEED "platinum is where it really does start to cost more." Morgan said that in some cases LEED platinum may make sense if, in the long term, there is an end user who will be saving a lot of energy. In the case of SLU, however, he explained that "the math was a little tougher for us to reconcile here because the dollars and cents of it weren't as compelling" (Morgan 2012).

High costs also limited Vulcan's ability to build autonomous, on-site, sustainable infrastructure in its buildings. According to Morgan, Vulcan wanted to include a bioreactor in one of the SLU buildings for on-site waste and water processing. This technology would have enabled water in the building to be recycled—from blackwater (sewage) to greywater—instead of dumping the blackwater into the sewer. Even though an on-site bioreactor would enable the building's plumbing to function without the use of the city's sewage infrastructure, the City of Seattle requires all buildings to hook up to their sewage infrastructure, in case a back-up system is necessary. The costs for city sewage hook up, and the county for wastewater processing, cumulatively cost hundreds of thousands of dollars, almost equal to the cost of an on-site bioreactor (Morgan 2012). To a developer, these additional costs make innovative environmental technologies an uneconomical investment (Morgan 2012). Vulcan also wanted to share resources and energy saved from onsite technologies (recycled water, recycled heat) among adjacent buildings owned by the developer. However, without city and citizen support in placing transmission infrastructure underground, in the public right of way, this was not feasible (Morgan 2012).

While cost was a significant factor in Vulcan's decision to not invest in an on-site bioreactor, Morgan commented that there was even greater difficulty in getting all of Seattle and King County's public agencies to approve such a technology. Morgan stated that early on in the project, the political will to implement these technologies just was not there. "You couldn't get all of the players to agree, or even show up, initially" (Morgan 2012). Morgan thinks that the City of Seattle wasn't prepared for the environmental nuances introduced in the development of SLU—that these ideas were too early. In an interview he stated that he thought there were "roadblocks because they were going by the book, instead of stretching their minds to think about how these technologies were coming" (Morgan 2012).

While the city's agencies and regulations may have been unprepared for nuanced "green" building features, these roadblocks also may have been the result of uncertainty surrounding the redevelopment from its inception. Lyle Bicknell stated that there were always "so many moving pieces, not certainty on any of them" (Bicknell 2012). One of the major moving pieces Bicknell referred to is the streetcar, which was not a guarantee during the initial stages of planning (Bicknell 2012). Other floating variables included availability of funds for neighborhood improvement projects, and what and where major road infrastructural changes would be made (Bicknell 2012). To this day, the idea of creating an energy district, as was proposed by Vulcan, where buildings could share heating and cooling needs, has been discussed but not committed to, due in part to coordination issues (Bicknell 2012).

Aids

Of the few local policies identified which aided in the integration of ecosystem services into SLU design, developer and city support for environmental infrastructure was at the top of the list. Lyle Bicknell emphasized the significance of having a local development community eager to help the city achieve its environmental goals. "Developers are doing this not out of any regulatory reason," Bicknell said, "but because they want to do the right thing environmentally." Similarly, Brandon Morgan commented that Vulcan continues to put green features in their buildings despite the fact that incentives cover only a small portion of the cost of these features. "Incentives are helpful," Morgan said, "but they are probably not enough to drive the decision making to do certain things like the under floor air distribution or the natural ventilation, all that stuff" (Morgan 2012)

In terms of regulatory policies which aided in the integration of ecosystem services into neighborhood design, Morgan stated that Seattle's more relaxed parking regulations saved developers a significant amount of money. In relation to energy consumption, Bicknell said that Seattle's energy code goes far to ensure efficient energy use. One of the strongest ecosystem services focused on in SLU was stormwater management. Bicknell commented that the City of Seattle contributed significant funding for the nuanced stormwater management system (the Swale on Yale), which enabled less conventional concrete stormwater management systems to be used throughout the neighborhood. This city financing was possible because, as Lish Whitson notes, since the project's inception, "environmental issues had a strong consensus among everyone" (Whitson 2012)

MONITORING EFFORTS

While SLU is still under construction, significant efforts have been made by the City of Seattle to monitor citizen use of the neighborhood and measure building energy consumption. Lyle Bicknell observed that the city does a "fair amount" of vehicle counts in the area, and is doing more and more pedestrian and bicycle counts (Bicknell 2012). Streetcar ridership is also tracked (Bicknell 2012). In January of 2010, Seattle passed the Seattle Building Energy Benchmarking and Reporting legislation (Ordinance 123226), a citywide ordnance that requires commercial and multifamily building owners to track their building's annual energy performance. The three main components of the ordinance are (Office of Sustainability and Environment 2011):

- Benchmarking building energy performance to establish the base-line energy consumption of the building and to guide future energy efficiency investments.
- Disclosure of building energy performance upon request to any potential tenant or buyer, so that they may compare building efficiencies and make more informed leasing or purchasing decisions.
- Reporting energy performance data to the City of Seattle to aid the city in monitoring progress toward energy efficiency targets and inform future policies and incentive programs.

The City of Seattle adopted this policy because the city believes this information will aid in reducing the 26 percent of citywide greenhouse gas emissions produced from energy consumption in buildings (Office of Sustainability and Environment 2011).

This citywide ordinance is informing projects in SLU. Brandon Morgan commented that Vulcan is just starting to get the first readings from the first 12 months of building occupancy from one of their buildings in SLU. From these data, Morgan said that Vulcan "will be studying our buildings a lot more to see what works, and what is the best technology" (Morgan 2012).

CONCLUSION

Though SLU is presently considered Seattle's most popular neighborhood for green living and biotech employment, redevelopment of the neighborhood has undergone significant disapproval from the Seattle community. Most recently, a series of articles has been published in *The Seattle Times* criticizing Amazon for not giving back enough to the city (like Microsoft), for having poor business practices, and for inundating SLU with employees and residents who contribute to neighborhood auto traffic and long lines for lunch (Boardman 2012). Other complaints from the community pointed to the lack of bicycle infrastructure in the neighborhood, the lack of a carbon sequestration program, and the infrequency of streetcar service (Bicknell 2012; Fucoloro 2010).

From an ecosystem services perspective, it will be difficult to assess the effectiveness of SLU until the development is complete. From this analysis, it appears that as of now, SLU does not meet the bicycle infrastructure, residential density, and walking distance to transit stops suggested in Calthorpe's TOD design guidelines. Given the information provided in SLU's plans, it appears that at full buildout, bicycle infrastructure and housing units per acre will be consistent with Calthorpe's TOD design guidelines. As SLU's residential population increases, however, the amount of greenspace per 1,000 residents will become inadequate.

Chapter 6: An Analysis of the Case Studies

The Case Studies: Lessons Learned

The Pearl District and SLU provide valuable lessons about planning and about Urban TODs that incorporate ecosystem services. First, both projects demonstrate that designing neighborhoods to incorporate ecosystem services into design and development is possible, and is most effective when planned for early on. VMT reductions was a key consideration in the early planning stages of the Pearl District, and today there exists excellent public transit, bicycle, and pedestrian infrastructure. In SLU, enhancing water quality and natural stormwater management was a primary planning goal from the outset, and remains the most innovative environmental design strategy in that neighborhood (as it is still under construction it is impossible to speak to its effectiveness). VMT reduction and public transit and bicycle infrastructure were not well integrated into SLU design early on, and are still recognized as major project shortcomings today.

While the case study neighborhoods illustrate that planning at the outset is essential in integrating ecosystem services into project design, they also reveal that oftentimes it is difficult to predict how a project ultimately evolve. For example, the Pearl District, according to Al Solheim, has evolved to be considered a “green” neighborhood, which was not foreseen at the outset of redevelopment (Solheim 2012). Urban planning that effectively incorporates and enhances ecosystem services takes time to mature. In the Pearl District, city data indicate more people are walking and taking transit, and thus the development is becoming more effective at reducing VMTs (Loveland 2012). The same is true for SLU—while streetcar ridership is increasing, it will take time to determine how effective SLU actually is at maintaining and enhancing ecosystem services (Bicknell 2012). As city agencies and developers in both Portland and Seattle are discovering, monitoring efforts are key to determining both short-term and long-term effectiveness of development that accounts for ecosystem services.

The case studies also illustrate that perceptions which evolve around different developments such as “green” TODs are not always accurate. The Pearl District, for example, praised for its urban parks, provides significantly less greenspace per thousand persons than is recommended by Clathorpe and the National Recreation and Park Association. Similarly, SLU, known in Seattle as an-up-and-coming, eco-friendly neighborhood, lacks bicycle infrastructure, an important component of such a neighborhood.

Most significantly, however, the case studies illustrate that in order to create TODs and incorporate ecosystem services into the urban environment, development must have the support of a progressive community of policy makers, developers, design practitioners, and citizens. As the discussions regarding barriers and aids to development indicate, national, regional, and state regulations implemented through local policy continue to dictate how the majority of the Pearl District and SLU are developed. Political support from municipalities and progressive policies or financial incentives can mean the difference, for example, between a project utilizing natural versus traditional stormwater management techniques. Environmentally sustainable development can be more costly or not aligned with local regulatory codes. Without an open minded community, progressive development that integrates ecosystem services into the urban environment simply is not possible. The following section further explores how progressive cities like Seattle and Portland integrate ecosystem services into local policy making, to ensure more environmentally sustainable local development.

ECOSYSTEM SERVICES IN PORTLAND AND SEATTLE POLICY MAKING

Portland

Policy makers in both Portland and Seattle commented that "ecosystem services" is a concept they strive to integrate into policy making in their respective cities. In Portland, Jonna Papaefthimio, the Planning and Sustainability Policy Advisor to Mayor Sam Adams, provided insight into how ecosystem services are integrated into Portland's urban policies and TODs, and the politics surrounding this integration. TODs and environmental planning are popular planning agendas in Portland. Papaefthimio noted that there are a number of city policies which encourage the integration of ecosystem services into TODs. One major policy which facilitates this integration, "the 20-minute neighborhood," was recently introduced in the recommended draft of the *Portland Plan* (City of Portland Government 2012). City officials believe that each household should be able to meet access desired and essential services—grocery store, coffee, newspaper, transit, and any other services frequently relied on—within a 20-minute walk from their home (this time frame includes transit time to get to these services) (Papaefthimio 2012). To achieve this goal, the city has made efforts to increase residential density in areas where several services already exist. Some of the policies introduced by the city to facilitate the 20-minute neighborhood include tax incentives and system development fee waivers to encourage grocery stores to locate in neighborhoods in need of food services, and to promote further investment to increase walking, bicycling, and transit systems (Papaefthimio 2012). Additional efforts have been made to ensure that regulatory policies in building code, like parking requirements, have been adjusted to promote more environmentally sustainable development (Papaefthimio 2012).

When asked about how the city government justifies the integration of ecosystem services into TODs, Papaefthimio observed that when Mayor Sam Adams supervised the

Bureau of Environment and Sustainability (BES), he initiated the citywide Grey to Green campaign. The primary goal of this campaign was to transition the city away from its total dependence on grey infrastructure—such as pipes and treatment plants—to a system somewhat reliant on green infrastructure. In this program, an emphasis was placed on the use of "street trees, bioswales, and natural stormwater treatments, or avoidance of needing treatments by promoting infiltration and options like that" (Papaefthimio 2012). Papaefthimio stated that the city has found that going from grey to green actually is less expensive. "A lot of how we talk about environmental services and the benefits," she said, "is about the cost savings of using green systems to provide services that we would otherwise have to pay for with gray infrastructure" (Papaefthimio 2012).

While the political justification is necessary for city budgeting and council, the people of Portland are very much in favor of extensive environmental policy. Papaefthimio commented that she thought the city may differ from other cities in that an ethos of environmental stewardship has been developing for decades. Though recent economic recession has led some people to claim that the city has invested more in trees than in people, in general, she said, people in Portland do "see the value of investing in green infrastructure and of having strong environmental policies" (Papaefthimio 2012).

In addition to constituent support of environmental policy, Papaefthimio believed having a unique form of government, and a mayor supportive of TODs and urban planning for sustainability, also seems to aids in the process of creating urban policy which integrates ecosystem services into development, particularly in TODs. The City of Portland has a commission system of government, unlike other large American municipalities, where the City Council is composed of the mayor and four city commissioners, all elected. Each commissioner is assigned a bureau within the city to supervise, and sets the policies and direction for that bureau. Mayor Sam Adams, who has always been interested in land use planning and design, was at one time was head of both the Bureau of Planning and the Bureau of Sustainability, and decided to merge the two into the Bureau of Planning and Sustainability. Adams and other commissioners have been a key factor in the progress of Portland's transit and sustainability planning initiatives (Papaefthimio 2012).

Seattle

In Seattle, Diane Sugimara, Director of Planning, and Richard Conlin, City Council member and Chair of the Planning, Land Use, and Sustainability Committee, provided information about how ecosystem services are integrated into Seattle's urban policies and TODs (while Conlin was familiar with the concept of "ecosystem services," Sugimara was not; for the purposes of the interview with Sugimara, ecosystem services were discussed in terms of environmental benefits). In Seattle, TODs are a popular planning mechanism, though still in the early stages of development (Sugimara 2012). Sugimara noted that there is considerable political support for TOD communities, and specifically from the Mayor, City Council, and planning commission. TODs also are consistent with Seattle's comprehensive plan, and the development that is occurring in the city's station areas (Sugimara 2012).

From the perspective of these policy advisers and makers, the City of Seattle has implemented a number of policies which encourage the integration of ecosystem services into TODs, and the greater urban environment. With green building, for example, Sugimara noted that the city has been a leader in transforming the local market to demand energy efficient buildings. The city has committed to build all LEED Silver government buildings and officials have been open about the benefits of this commitment Seattle's citizens and development (this commitment was increased to LEED Gold last year). To encourage green building, Seattle has passed an ordinance supporting the Living Building Challenge. Sugimara stated that if someone commits to developing a living building, then the city will allow departures from numerous building code standards to make the building process easier. Colin identified other city policies that facilitate the integration of ecosystem services into the urban environment:

> We have a policy framework that involves, for example, drainage, that basically says employing natural drainage systems is our preferred alternative for any kind of drainage related issue. In order to do something other than that, we have to demonstrate that it is not possible to produce drainage benefits using a natural drainage system (Conlin 2012)

Like Portland, the City of Seattle has made significant efforts to make sure that building codes, and other regulations such as parking and landscape requirements, do not interfere with more sustainable development practices (Sugimara 2012).

Sugimara explained that the political justification for incorporating environmental policies within developments, for the purpose of enhancing the natural environment, goes back years. A strong environmental ethic in Washington State has been present for decades, and environmental and shoreline regulations at the state level date back to the early 1970s (Sugimara 2012). The State Growth Management Act, passed in 1990, determined that uncoordinated panning efforts with inconsistent goals throughout the state were detrimental to the Washington's "environment, sustainable economic development, and the health safety and high quality of life enjoyed by residents of [the] state" (Washington State Legislature 1990, RCW 36.70A.010)

The Act outlined environment, land use, and development goals, and required jurisdictions with populations greater than 20,000 people to create a comprehensive plan and regulations consistent with these goals (Sugimara 2012). The State Growth Management Act has resulted in the implementation of environmentally critical regulations at local levels, and provides Seattle with both guiding principles for development and the political justification for incorporating ecosystem services into urban environmental policies (Sugimara 2012).

Richard Conlin observed that ecosystem services are real, they are important to people, and "they make a difference in the way in which lives in communities operate" (Conlin 2012). For Conlin, incorporating ecosystem services into any development strategy is rational. Typically, this incorporation needs to be paired with a cost benefit analysis for political justification. "In any development strategy, you need to take [ecosystem services] into account and incorporate them, otherwise you're not creating a rational strategy" (Conlin 2012). While monetizing ecosystem services and environmental return can be very challenging, this is what is usually done to obtain the political support for policies that integrate ecosystem services into urban planning and TODs.

In general, Conlin and Sugimara believe that policy makers, developers, and people of Seattle place a high value on ecosystem services in their integration into TODs and urban development. Sugimara explained that in Seattle politics, there are several City Council members who support strong environmental regulations. One of the city's greatest supporters is the current mayor, Mike McGinn, who used to be state chair of the Washington Sierra Club (Sugimara 2012). There is also strong support for environmentally sustainable development from developers themselves. Sugimara stated that developers in Seattle are raising the bar for green development by frequently incorporating LEED and Living Building standards into their projects. The voting population too is supportive of and values policies for sustainable development. Conlin said that interestingly, while most of his constituents "place a very high value on environmental quality and stewardship," this value is oriented, in part, around aesthetics, in addition to a general view of environmental benefits (Conlin 2012).

While there is general support among these groups in Seattle for policy that facilitates environmental sustainability, there also exists some debate. While in theory people support reducing parking requirements and investing in bike lanes and pedestrian infrastructure, in practice they do not want to feel forced out of their vehicles (Sugimara 2012). In a similar way, while citizens support denser neighborhoods, they do not want density in their own neighborhood (Sugimara 2012). Other debates include discussion about the "free rider" problem of environmental investments, and evaluation of the actual environmental and human benefits received from investments (Conlin 2012).

While ecosystem services in Seattle policy making far exceed the U.S. standard, Conlin believes the following three major changes need to take place in the near future to resolve these debates, and further facilitate the integration of ecosystem services into urban policy. He listed these changes as the following (Conlin 2012):

1. Getting the concepts [ecosystem services and related ideas] accepted in the community.
2. Getting the concepts accepted amongst decision makers.
3. Taking that concept and actualizing it—coming up with the actual numbers and formulas for demonstrating that you are actually able to accomplish what you are aiming at.

CONCLUSION: THE VALUE OF ECOSYSTEM SERVICES IN PORTLAND AND SEATTLE

From the information obtained in these interviews with policy makers from Portland and Seattle, it can be concluded that ecosystem services, though rarely identified in either city as ecosystem services, have been highly valued in these cities for generations. As the answers of the policy maker interviewees indicate, ecosystem services, more commonly referred to as environmental benefits, are highly regarded by policy makers, developers, design practitioners, and constituents alike. This value is reflected in the environmentally progressive policies discussed in this study, which continue to aid in the integration of ecosystem services into the Pearl District and SLU.

The high value of ecosystem services in Portland and Seattle are also apparent from the design of each of the case study TODs. In the Pearl District, practitioners repeatedly stated the inherent environmental benefits associated with VMT reductions were central to neighborhood design early on in development. In SLU, increasing greenspace and natural stormwater infrastructure to improve local water quality was a central tenant of neighborhood design.

Chapter 7: Conclusion and Recommendations for Future Policies and Research

The data in this study support the conclusion that urban planning and the development of TODs provide a significant opportunity to enhance the ecosystem services of the natural environment. Through information obtained in interviews with academics, policy makers, and design professionals, this study has illustrated that there is significant value in incorporating ecosystem services into the design and development of TODs. This study has further demonstrated how TOD planning both in theory and in practice, can incorporate the following four ecosystem services, most related to VMT reduction and the addition of open space, into design and development:

1. Climate regulation (local and global).
2. Fuel.
3. Processing and detoxification (urban hydrology and urban air quality).
4. Open Space, Habitat Preservation, and Recreational Services.

As the need for higher quality resources in cities becomes more pressing, federal and local environmental policy encourages urban planning and development for sustainability that maintains and enhances ecosystem services. For TOD planning, progressive local policies tend to be most effective at facilitating the integration of ecosystem services into project design.

The following sections explore the general political barriers and aids to TODs that integrate ecosystem services into design. Suggestions for future policies to further facilitate this integration, determined from information provided by academics and design practitioners in interviews, have been provided. This chapter concludes with recommendations for further research regarding the integration of ecosystem services into TODs and urban planning.

GENERAL POLITICAL BARRIERS

In addition to the political barriers to creating more environmentally sustainable development identified by practitioners in Portland and Seattle, the academics and planners, landscape architects, architects, and policy makers interviewed for this study, identified general barriers to all development which integrates ecosystem services. Cost was commonly cited as the greatest barrier to environmentally sustainable development. In an interview, Ken Yocom noted that "ultimately what it always comes down to is economics, and whether the cost and benefit balance sheet actually work together." Danielle Pieranunzi, the Director of SITES, added to this statement, saying that the lack of availability of economic data describing the benefits of environmentally sustainable development in monetary terms, contributes to the misconception of the cost of this type of development, thereby adding to the perception of cost as a barrier (Pieranunzi 2012). Cathleen Sullivan, a transportation planner at Nelson Nygaard, added:

> To a large degree, it is very difficult to prove to a developer how they will make a profit at the outset, the long run costs [of environmental development] are hard to prove (Sullivan 2012)

Regulatory barriers, such as limitations on height and FARs limit the intensity of development possible in certain locations and were also cited by practitioners are barriers to environmentally sustainable development. Other regulatory barriers were identified by Julie Raish, who stated that in some places, the addition of green infrastructure to one's private property, such as green roofs or rain gardens can be very difficult. Green roofs are not always consistent with building codes, and placing a rain garden near the street, in the pedestrian right of way, can be illegal (Raish 2012).

Above all, however, academics and practitioners alike agreed that political will and education are the greatest contributors to all barriers. Without political will for environmentally sustainable development, the lobby does not exist to create environmentally progressive policy. As there are often times huge obstacles with planning, and the political climate of a place influences planning at all levels, political will is crucial to ensuring that ecosystem services are strongly considered in the development process (Franklin 2012). Particularly at the local level, the lack of political will can result in a huge loss of opportunity for environmentally sustainable planning. Jason Franklin, a planner and Division Manager at Parametrix, an environmental planning firm in the Northwest, observed that it is “at the comprehensive plan level that you see the most effective policy which integrates ecosystem services into any development” (Franklin 2012).

Lack of education about environmental issues, and language barriers surrounding environmental issues, are among the greatest contributors to deficient political will. While some of the academics and practitioners interviewed cited the existence of a language barrier in policy making as a barrier to environmentally sustainable development, others argued that the general lack of education about environmental issues was an even greater barrier. Uncertainty surrounding environmental issues, most notably climate change, makes it difficult, in some areas, to create and implement policy to mitigate climate change (Silverman 2012). The lack of substantial environmental education at all levels, poses roadblocks to creating more sustainable development (Pieranunzi 2012).

General Current Policies for Integration

Despite the numerous barriers to creating development that incorporates ecosystem services into design, the academics, practitioners, and policy makers interviewed identified a number of current policies that they have encountered in their practice and research which facilitate this integration. The majority of policies identified were local, and regulatory based. Mark Simmons of Austin, Texas remarked that in his experience in designing to enhance ecosystem services, all of Austin's citywide regulations about surface water flow, infiltration, and stormwater mitigation have come to his aid (Simmons 2012). He stated that Austin's progressive policies regarding green roofs also have been effective. Kristina Hill observed that all over the country, local green streets legislation "is helping people link stormwater issues, urban heat island effect, and multi-modal transportation to the design of urban public spaces." Ken Yocom commented that the City of Seattle has created a lot of policy to both require and encourage green building. One such initiative requires any building over 5,000 square feet (about 465 square meters) to meet LEED standards (Yocom 2012). According to Yocom, at the citywide level, Seattle has done a great job identifying neighborhoods for high-density development and "attempting to funnel money from that direction to promote development in those areas, as part of building up transit opportunities" (Yocom 2012)

Current regulatory policies that facilitate the integration of ecosystem services were also identified at the state and national levels. Oregon's statewide mandated planning system requires each jurisdiction to have its own, legally binding comprehensive plan (Franklin 2012). Each comprehensive plan reflects both statewide and local goals. In environmentally progressive states like Oregon, mandating local comprehensive plans seek to meet environmental goals is a very effective tool for creating development which integrates ecosystem services into design (Franklin 2012). At the federal level, environmental policy such as the Clean Air Act has been particularly effective in the creation of legislation that contributes to cleaner air, most notably mass transit-oriented policy (Grantham 2012). One example of this is the Transportation Equity Act for the 21st Century (TEA-21), a federal policy that "allowed people to link multiple modes of transportation to automobile transportation," and therefore create more efficient and diverse transportation systems and options (Hill 2012).

At all levels, advocacy groups have been effective in educating populations about the benefit of environmentally sustainable development, and at inciting political will. Hill noted that the:

> neo-traditional design advocacy groups have helped people think about using multiple modes of transport to get to public transit, within pedestrian-oriented neighborhoods that are built with local materials and include public space systems that could do their 'work' like stormwater mitigation, biodiversity and cultural resources conservation, heat mitigation, etc. (Hill 2012)

Starting around 2004, a couple in Seattle began leading international sustainability tours for members of the building community—developers, engineers, architects, landscape architects, and public officials—to show how environmentally conscious countries like Denmark and Sweden were approaching sustainable development (Sugimara 2012). Initially, not all practitioners who participated in these trips were interested in sustainable development, but were merely participating to know what their competition was learning (Sugimara 2012). Most individuals who have returned from these trips, around 200 to 250 (mostly from Seattle and the Northwest), have come back proponents of sustainable development. This has been reflected in the change in development philosophy within the city (Sugimara 2012).

RECOMMENDATIONS FOR FUTURE POLICIES FOR INTEGRATION

Policies that facilitate and hinder the integration of ecosystem services into TODs and urban planning have been identified in previous chapters. This section outlines policies that have been helpful, and are suggested by Calthorpe's TOD guidelines and the planning, landscape architecture, architecture academics and practitioners, and developers and policy makers, as policies that should be adopted in the future by all municipalities to further facilitate this integration.

The TOD design strategies outlined in Chapter 3 enhance the following four ecosystem services:

1. Climate regulation (local and global).
2. Fuel.
3. Processing and detoxification (urban hydrology and urban air quality).
4. Open Space, Habitat Preservation, and Recreational Services.

Policies that encourage TODs as a planning strategy, and the design strategies that enhance these ecosystem services should be encouraged. Policies that encourage TODs include urban growth boundaries, zoning for mixed-use and medium- to high-density, and funding which supports the introduction and growth of transit systems like light rail and commuter rail. Policies that would encourage use of the Calthorpe's TOD design strategies which enhance ecosystem services would include either regulatory or incentive-based programs to support (Calthorpe 1993):

- Urban infill development.
- Intense commercial, housing, and office land uses in areas located near transit, including mixed-uses in buildings.
- Additional parks and public space.
- Street and pedestrian connectivity.
- Resource conservation, including the protection of existing drainageways and wetlands, creeks, riparian habitat, slopes, and watersheds.
- Wastewater treatment and water reclamation through green infrastructure
- The use of indigenous and drought tolerant landscaping.
- Energy conservation.

- Economic regulation to prevent competing commercial uses.
- Extensive bikeways and bike parking.
- Comfortable sidewalk widths for pedestrians.
- Additional arterial crossings and where not possible, pedestrian bridges.
- Additional street trees.
- Reduced parking standards.
- Reduced size of surface parking lots.
- Increased permeable surfaces on parking lots.
- Transit efficiency and system expansions.

From interviews with practitioners involved in the case studies, it appears that policies which provided monetary incentives for green building, green wastewater infrastructure, energy efficient efficiency, and post-occupancy monitoring, have been effective in encouraging developers to facilitate ecosystem services into TODs. Regulatory policies which mandated property easements for additional greenspace, designated neighborhoods as TIFs, and reduced parking requirements were also effective. Design strategies demanded by the market, such as energy efficient buildings, for which progressive companies and residents were willing to pay a premium, also encouraged the integration of ecosystem services into development. Ultimately, the fact that each neighborhood was supported by transit created the market demand necessary to stimulate any type of development in this area.

In addition to identifying current policies that facilitated the integration of ecosystem services into the Pearl District and SLU, practitioners provided suggestions for future policies which would be helpful in further facilitating this process. Suggestions for regulatory and incentive-based policies included:

- More relaxed parking requirements (Loveland 2012).

- Enabling private development in the public right of way (Morgan 2012).
- More flexible building codes (Stastny 2012).
- Reduced municipal fees for decentralized infrastructure (Morgan 2012).

Academics and practitioners also provided suggestions for future policies to enhance urban ecosystem services, and to further facilitate the integration of ecosystem services into TODs and urban planning in general. To encourage TODs, the most common policy suggested was a mandated urban growth boundary, which has the function of encouraging infill development (Grantham 2012). To enhance the ecosystem services within TODs and urban environments, regulatory and incentive-based policies were suggested. Regulatory policies were identified as more effective for larger scale initiatives at national and state or regional levels. Incentive-based policies were recommended for smaller jurisdictions at the community or watershed scale (Yocom 2012). Jason Franklin stated that regulatory policies are especially significant when it comes to ecosystem services because they are almost always necessary to create market-based solutions. Franklin commented that you “can’t just have a purely market-based solution, and you can’t have a purely regulatory solution either—it needs to be both” (Franklin 2012). The suggested regulatory policies identified by academics and practitioners included:

- More flexibility in parking requirements (Sullivan 2012).
- More flexibility building envelope requirements (Sullivan 2012).
- Form-based code or building code which mandates greenspace and green building (Grantham 2012).
- More flexibility in building private green infrastructure in the public right of way (Raish 2012).

- Creating a trading scheme under which development rights or ecosystem services could be traded among property owners and developers (Franklin 2012).

Unlike the majority of academics and practitioners, Steve Windhager advised against creating more environmental regulations without extensive research. He commented:

> I think if we went in first with regulatory approaches we'd end up codifying something that would end up not being what we want in 5 or 10 years. I would encourage us to step into the regulatory approach pretty lightly, because I don't think we know how to regulate this stuff yet (Windhager 2012)

Windhager cited recent research which found that greenroofs may not have any environmental benefit whatsoever, as an example of a regulation which, if enacted now, may be found as not suitable for the enhancement of ecosystem services in the near future (Windhager 2012). Windhager did support market-based incentive strategies like rating systems as initial measures to further integrate ecosystem services into TODs and urban planning. But again, he noted that it is good performance that should be incentivized, not simply a design strategy (Windhager 2012).

Academics and practitioners also suggested a number of other incentive-based policies that would have a beneficial affect on further incorporating and enhancing a variety of ecosystem services into TODs and the urban environment. These policies included providing government tax and development incentives (including density and FAR bonuses) for:

- Planting trees (Simmons 2012).
- Conservation and protection such as wetlands banking systems (Yocom 2012).
- Increasing productive urban greenspace (Windhager 2012).
- Property easements (Yocom 2012).

- Greenroofs (Raish 2012).
- Property owners who reach beyond their site's borders to make development decisions that benefit the city and region at large (Pieranunzi 2012).

Another suggested policy included creating regulations that required an end goal without specifying how to get there, thus enabling developers to implement innovative design strategies to meet performance goals (Hill 2012). According to Kristina Hill, the "openness to unique solutions is the carrot" (Hill 2012). Other practitioners emphasized the importance of policies which either mandate or encourage post-occupancy monitoring. Danielle Pieranunzi stated that "monitoring is just so essential that it isn't just about design but actually monitoring it afterwards" (Pieranunzi 2012). She believes that creating demonstration sites, where new and unique solutions may be tested for efficiency and effectiveness, is one of the greatest opportunities for more environmentally sustainable development (Pieranunzi 2012).

IDEAS FOR FURTHER RESEARCH

Much research still needs to be conducted regarding the relationship between ecosystem services and urban planning, as well as the integration of ecosystem services into urban planning. First and foremost, research should be conducted to establish the relationship between this concept and practice. Additional research to be explored once this relationship is more concretely established are outlined in the following paragraphs.

One of the greatest questions to be explored surrounds the effectiveness of the still relatively young term "ecosystem services." In interviews with academics and practitioners, while all stated that they placed a high value on ecosystem services in practice, many were uncomfortable providing a definition for the term. The responses regarding the effectiveness of "ecosystem services" as a way to discuss environmental considerations in the development context were also varied. Mark Simmons commented that he believed the term was as effective as "sustainability" for talking about development. Other practitioners favored "sustainability" over "ecosystem services," and believed that the adoption of another term that can mean something similar is likely to confuse people unfamiliar with the concept. Some practitioners commented that ecosystem services sounds too technical, possibly like a landscape architecture firm, and that out of context it does not make sense. Other practitioners, like Ken Yocom believe the word is highly effective. "From my perspective," Yocom commented, "it gives more, it helps to understand both where it is coming from and what it provides" (Yocom 2012). Danielle Pieranunzi said that while she remains unsure if it is the best term, it is "the right term for right now," and is more frequently "being used in different circles, from the corporate business world to city planning to landscape design" (Pieranunzi 2012).

Policy makers who place a high value on these services in their daily practice, while familiar with the term "ecosystem services" also were divided as to the effectiveness of the term. Jonna Papaefthimio considered the term to be effective in policy making, at least in Portland. She commented, that "[the term ecosystem services] helps people to think about the services that are supplied by the environment that we would have to otherwise pay to get" (Papaefthimio 2012). Richard Conlin, on the other hand, commented that he thinks "it's not the greatest term." Conlin expanded upon this, stating:

> I think for most people [ecosystem and services] sound a little bit too technical, and if you isolate them from each other, then it is hard to know exactly what you are talking about, and when you put them together, it really sounds not particularly exciting (Conlin 2012)

Recently a study sponsored by The Nature Conservancy was conducted to determine if the voting population of the of the United States understands the term "ecosystem services" and supports the use of that concept being used to influence decisions about natural resource management (Metz and Weigel 2010). While the results revealed that the majority of voters identified "nature's benefits" as very important and supported integrating these benefits into decision making, voters would prefer to call these benefits something other than "ecosystem services" (see Table 4 below for preferences of alternative terminology).

Name	**% Rating a 6 or 7 *(Very Appealing)***	**Mean Score**
Nature's Value	**61%**	***5.5***
Nature's Benefits	**53%**	***5.3***
Earth's Benefits	**55%**	***5.2***
Environmental Value	**49%**	***5.2***
The Planet's Assets	**45%**	***5.0***
Nature's Health and Safety Systems	**46%**	***4.9***
Environmental Wealth	**45%**	***4.9***
Environmental Goods	**44%**	***4.9***
Natural Life-Support	**44%**	***4.9***
Ecological Wealth	**42%**	***4.8***
The Planet's Products and Services	**34%**	***4.6***
Natural Infrastructure	**32%**	***4.6***
Ecosystem Services	**31%**	***4.5***
Nature's Social Safety Net	**34%**	***4.4***
Natural Capital	**30%**	***4.3***
Earth's Capital	**29%**	***4.2***

Table 4: Alternative terms for "ecosystem services" preferred by American voting population (Metz and Weigel 2010, 6)

This research regarding the effectiveness of the term "ecosystem services" to professionals, in policy making, and to the general public is a start, but more needs to be done. Ideas for further research would be to expand upon public and professional perception of the term ecosystem services, and determine the shortcomings of words in the current lexicon such as "climate change," "global warming," and "sustainability," from public perception, action, and policy making perspectives.

Further research to support more effectively integrating a greater variety of ecosystem services into the urban environment would also be beneficial. Steve Windhager presented the idea of conservation versus production of ecosystem services in the urban environment. Literature about this unique perspective has yet to be published. Exploring ways to increase productive spaces in cities, especially within TODs, is an uncharted and highly significant area of research. Quantitative analyses which reveal the monetary savings of enhanced ecosystem services to developers, practitioners, policy makers, and municipalities also is an area where more information would be beneficial and would likely influence these parties to integrate ecosystem services into the urban environment. Studies exploring the benefits (monetary and non-monetary) of post-occupancy monitoring programs is an example of an area of quantitative ecosystem services analysis which can be used as a resource for decision making by these parties. Further reviews of how ecosystem services are integrated into TODs or other types of urban planning initiatives also would be beneficial.

Further exploration into ways in which ecosystem services may be effectively and cohesively regulated in the future to ensure the quality and quantity of urban and regional ecosystem services also is necessary. This idea was explored, to a small degree, in the interviews conducted for this study, but like the question of effectiveness of the terminology, there was no consensus on how to regulate ecosystem quality and quantity and who would oversee this cohesive regulation. Some academics and practitioners interviewed believed that a new governing body would be necessary to oversee that the quality and quantity of ecosystem services are enhanced, and that the various agencies do not contradict one another. Other practitioners, like Ken Yocom, believe the regulatory bodies and mechanisms already exist to over see efficient regulation, and that adding another level of government would not be helpful. Yocom stated:

> Part of [successful regulation] is just about focusing the ideas, focusing the regulations in new directions or trying to build upon it, instead of looking at, say, individual parcels, actually understanding the larger context, the ecological and ecosystem context through which these parcels are developing or being redeveloped and moved around (Yocom 2012)

Mark Simmons agreed that the proper regulatory bodies already exist, and suggested that regulation of ecosystem services could be equally spread across different governing bodies, especially between the EPA and the USDA. Steve Windhager said that while a separate governing body would not be necessary, there would have to be an overarching agreement about the definition and bench marks for successful ecosystem services health and regulation. According to Windhager:

> when you have a standardized way of understanding ecosystem services, than any regulatory body would be able to speak one voice to other regulatory bodies, consultants, and to the public (Windhager 2012)

FINAL THOUGHTS

As the world's urban populations increase, ensuring the quality and quantity of the ecosystem services is essential. Methods to further integrate ecosystem services into urban environments are vital. Urban planning, and TOD in particular, provide a significant opportunity to incorporate ecosystem services into urban design and development. As this research shows Calthorpe's model TOD, commonly adopted by cities, is effective in reducing VMTs and increasing open space, habitat, and urban water quality. However, this model can be redesigned to integrate even more valuable ecosystem services into cities. For example, a TOD with additional open space acreage may *produce* the following ecosystem services:

- Food production.
- Pollination services.
- Renewable power generation.

The research conducted for this paper also indicates that ecosystem services are highly valued by design academics and practitioners, developers, and policy makers. But this support only goes so far. Without local policies that facilitate more environmentally sustainable urban development, greater integration of ecosystem services into the metropolis is not possible. Therefore, in moving towards an ecologically sustainable future, environmental education, activism, and discussion across disciplines will be critical in order to incite the political will necessary to create progressive environmental policy. Further research also is necessary to determine more precisely the complex relationship between ecosystem services and urban planning. Finally, more research is needed to establish the most effective vocabulary for environmental policy making and design strategies for ecologically sustainable development.

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